U.S. Coast Guard Research and Development Center

1082 Shennecossett Road, Groton, CT 06340-6096

Report No. CG-D-01-99, III

Investigation of Fuel Oil/Lube Oil Spray Fires On Board Vessels

Volume III

Incident Databases

Appendix C:	**LMIS Events and Associated Event Trees/Event Characterization Tables**
Appendix D:	**Nippon Kaiji Kyokai (NK) Event Characterization Tables**
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FINAL REPORT
NOVEMBER 1998

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Marine Safety and Environmental Protection (G-M)
Washington, DC 20593-0001

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Technical Report Documentation Page

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15. Supplementary Notes

The U.S. Coast Guard Research and Development Center's technical point of contact is Richard Hansen at 860-441-2866.
The U.S. Coast Guard Headquarters project sponsor is Matthew Gustafson at 202-267-0170.

16. Abstract (200 words or less)

The U.S. Coast Guard sponsored this project to assess control measures (technological advancements as well as safety management systems) for preventing or mitigating the impacts of fuel oil or lube oil spray fires on board vessels, particularly in the engine room. For this purpose, we identified a number of proposed control measures to prevent/mitigate the impacts of spray fires, and then we evaluated the reduction in risk that can be expected from the implementation of each measure. As part of our evaluation, we identified many sources of relevant incident investigation reports. These sources provided a total of 143 fires caused by releases of fuel oil/lube oil; of these 9 are known to have resulted in fatalities, and another 8 are known to have resulted in personnel injury.

Our research findings substantiated several (and refuted a few) previous findings/beliefs regarding spray fires. In addition, our investigation resulted in 18 feasible, practical control measures (recommendations) to reduce risks associated with fuel oil/lube oil spray fires in engine rooms. The first 12 recommendations address specific changes to 1) existing fuel oil/lube oil equipment and systems and 2) management issues. The next three recommendations address more significant changes to fuel oil/lube oil equipment, and they are presented for new (or significantly modified) ships. We also identified two areas that require additional research and development efforts, and we developed two recommendations to address these areas. Finally, we determined that much of the risk associated with fuel oil/lube oil spray fires stems from deficiencies in (or lack of) safety management systems. That is, the root cause of these incidents is generally the absence of, neglect of, or deficiencies in management systems.

This report consists of three volumes. Volume I contains a summary of these practices. Volume II consists of Appendix A: MISREP Events and Associated Event Trees Characterization Tables; Appendix B: MSIS Events. Volume III consists of Appendix C: LMIS Events; Appendix D: Nippon Kaiji Kyokai (NK) Events; Appendix E: TSB Events; Appendix F: MIIU Events; Appendix G: NTSB/MAR-95/04 Events; Appendix H: Preliminary Recommendations; Appendix I: Qualitative Analysis of Oil Spray Incidents; Appendix J: Evaluation of theImpact of Preliminary Recommendations; Appendix K: Resumes of Hazard Evaluation Team Members; and Appendix L: June 16-17, 1997, Trip Report.

17. Key Words	18. Distribution Statement
fuel oil, lube oil, fire, spray, risk, hot surface, inspection, maintenance, strainer, duplex strainer, engine room, ship, vessel	This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. SECURITY CLASSIF. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

METRIC CONVERSION FACTORS

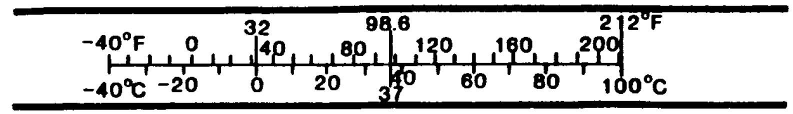
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



APPENDIX C

LMIS Events and Associated Event Trees/Event Characterization Tables

This attachment presents the analysis of selected events from the database developed and maintained by Lloyd's Maritime Information Services Limited (LMIS).[a] LMIS is a private limited company owned jointly by Lloyd's Register of Shipping and Lloyd's of London Press Limited. LMIS was formed to enable the world's maritime community to have access to the maritime information that has been gathered and collected by the two parent companies over the past 200 years.

The LMIS database contains information about all reported serious casualties, including total losses, to all propelled seagoing merchant ships in the world of 100 gross tonnage and above from January 1, 1978. Also, the database contains all reported incidents (i.e., serious and nonserious) to tankers, including combination carriers and gas carriers/tankers, since January 1, 1975. The database is maintained on a mainframe computer at Lloyd's Register, and it is updated from reports received daily from Lloyd's agents and Lloyd's Register surveyors located in more than 130 countries.

At our request, LMIS performed computer searches to identify all events in the database where a fire/explosion occurred and the incident involved fuel oil and/or lube oil systems.[b] The computer searches generated a total of 42 records that have been reported in the public domain since 1978. This attachment presents the analysis of these events in two pages for each event:

- The Lloyd's Register (LR) number, the degree of severity assigned by Lloyd's Register, and an event description. The degree of severity refers to the amount of damage that resulted from the fire/explosion, and it is either total (T), significant (S), or not significant (N). The event description is taken directly from the LMIS database (we have not edited or modified these descriptions)
- On the same page, the event description is followed by an event characterization table, which supplements the event tree with comments (as documented in or as inferred from the LMIS event description) about the system/location, cause, ignition source, means of detection, means of release isolation, means of fire suppression, impact on propulsion, impact on steering, human casualty, and corrective action
- An event tree, which shows the sequence of events associated with the event

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[a]*Casualty File Specification*, Lloyd's Maritime Information Services Limited, London, UK, May 1995.

[b]Letters (with computer diskettes) to Henrique Paula of JBF Associates, Inc., from Alex Gray, Marketing Manager for Lloyd's Maritime Information Services Limited, London, UK, January 6 and February 11, 1998.

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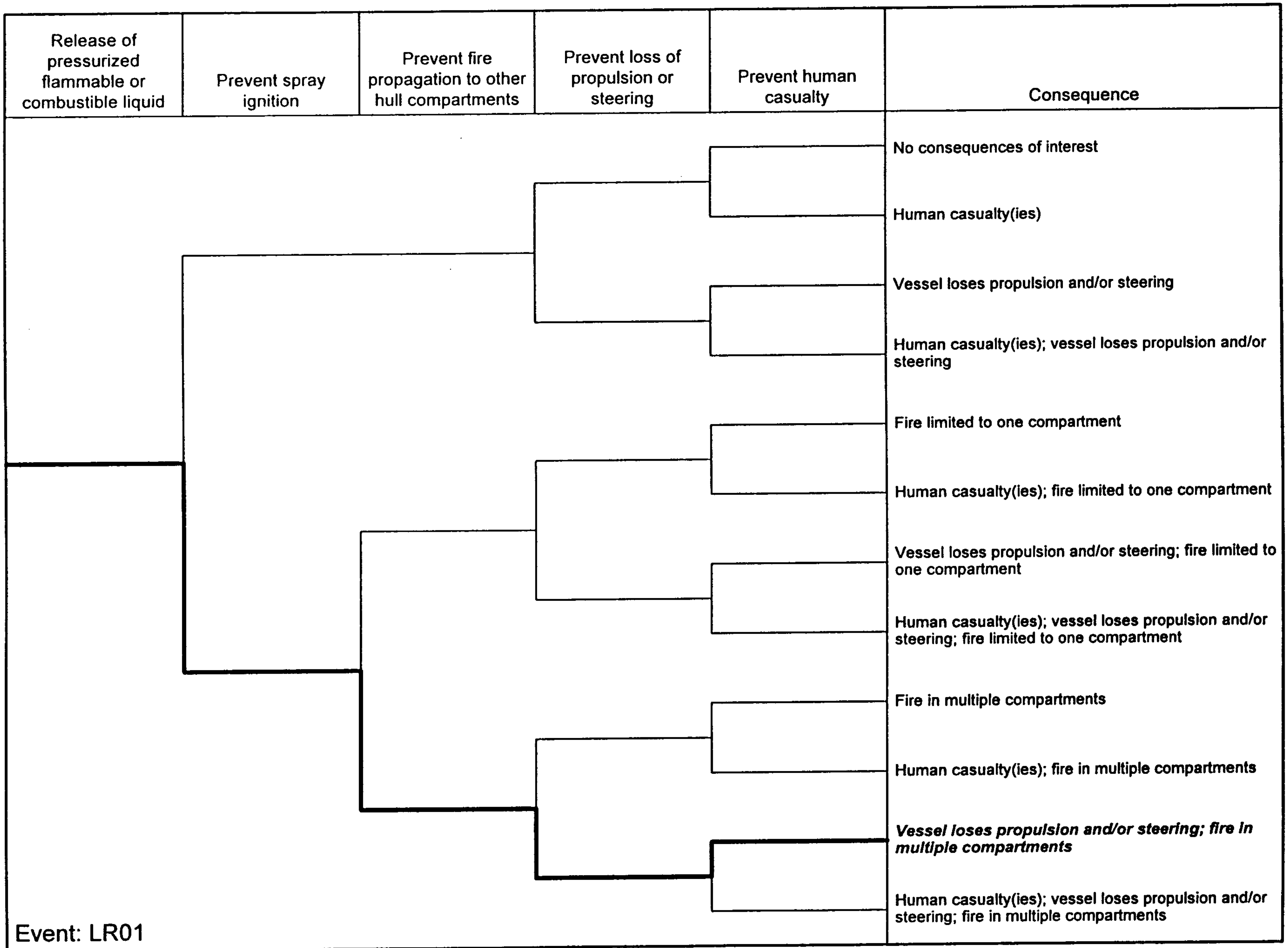
LR Number: 5028538 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM 600 MLS E. OF JACKSONVILLE IN LAT.29 50N., LONG.71 00W., ON 1/8/71. TOWED TO HAMPTON ROADS AND THENCE TO TAMPA FOR REPAIRS.

UPPER SECTION OF ENGINE ROOM AND AFT ACCOMMODATION BURNT. FIRE DUE BREAKAGE OF LUBRICATING OIL PIPE FOR FORWARD TURBO BLOWER RESULTING IN SPRAYING OIL OVER HOT MAIN ENGINE EXHAUST MANIFOLD.

Event Number: 5028538 (LR01)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Pipe failure	
Ignition Source	Hot surface (main engine exhaust manifold)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – repairs were conducted in Tampa	Not inferred



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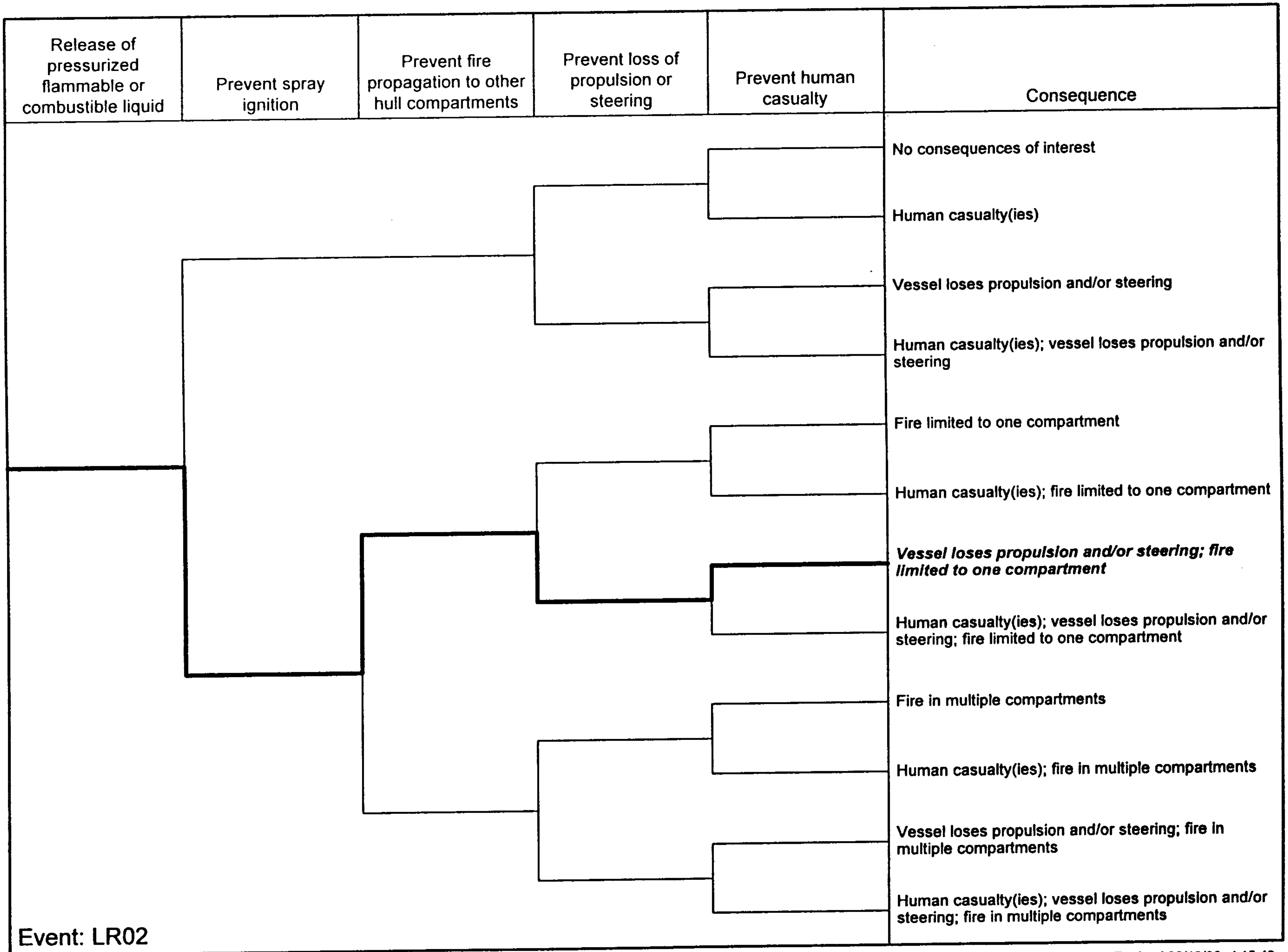
LR Number: 5107827 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM 300 MLS E. OF CAPE KENNEDY ON 25/11/70 AFTER LUB. OIL LINE FRACTURED. FIRE EXTINGUISHED IN 2 HRS., SUBSEQUENTLY TOWED TO JACKSONVILLE WHERE REPAIRS EFFECTED.

WIRING AND MAIN SWITCHBOARD EXAMINED AND PART RENEWED.

Event Number: 5107827 (LR02)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Lube line cracked	
Ignition Source		Hot surface (turbocharger casing)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – wiring and main switchboard were examined and some parts were replaced	Not inferred



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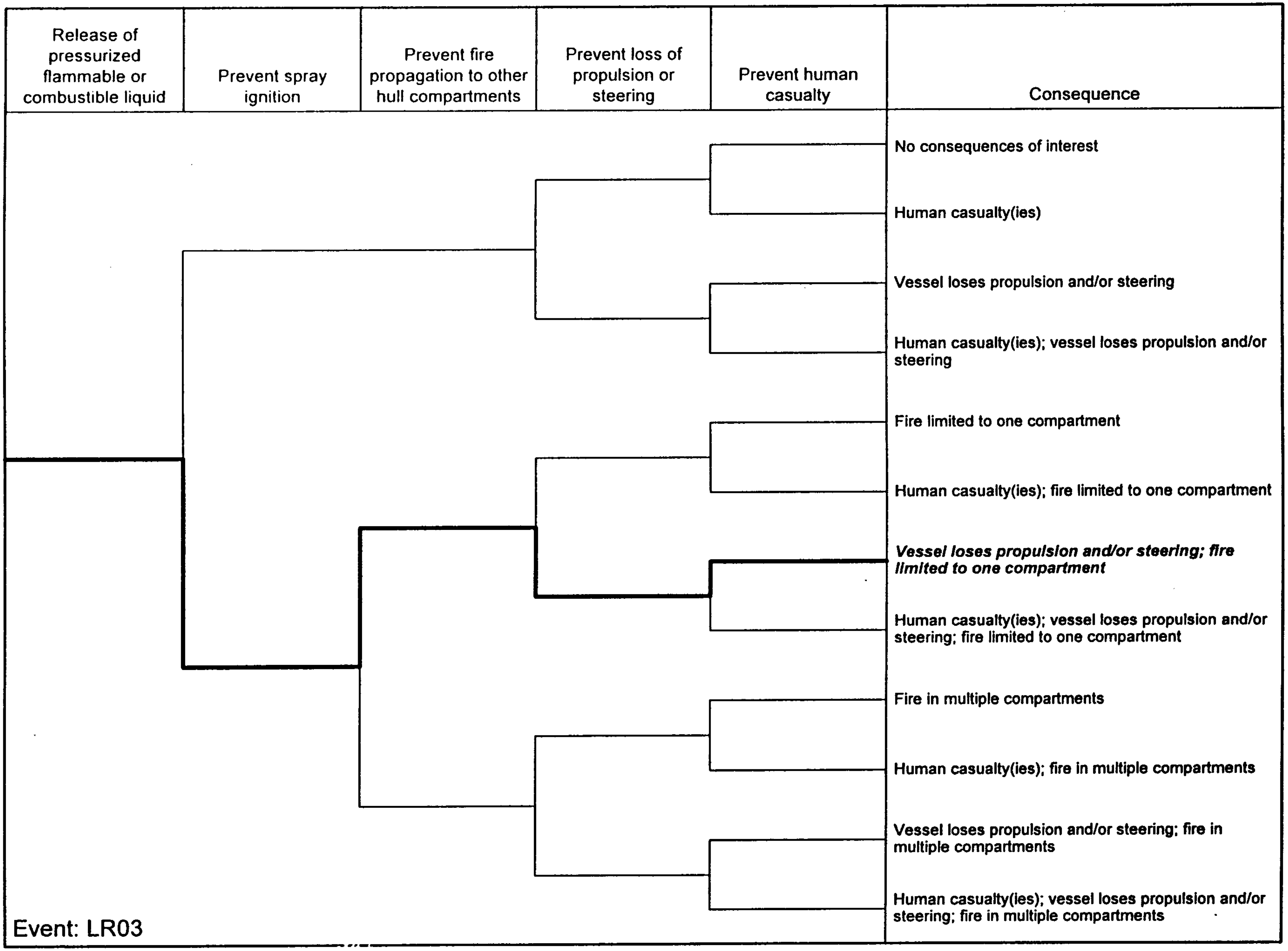
LR Number: 5237115 Degree of Severity: T

DAMAGED BY EXPLOSION AND FIRE IN ENGINE ROOM WHILST LAID UP AT SEYCHELLES ON 8/12/82; SUBSEQUENTLY TOWED TO KARACHI, SOLD AND BROKEN UP.

REPORTED HIGH PRESSURE FUEL OIL PIPE BURST IN WAY OF BOILER FRONT. FIRE DAMAGE CONFINED TO BOILER AREA PORT SIDE AFT AT LOWER PLATFORM LEVEL OF ENGINE ROOM. MAIN ENGINE DAMAGED BY WATER DURING EXTINGUISHING OPERATIONS.

Event Number: 5237115 (LR03)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Pipe burst in way of boiler front	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Water	
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was sold for dismantling	Not inferred



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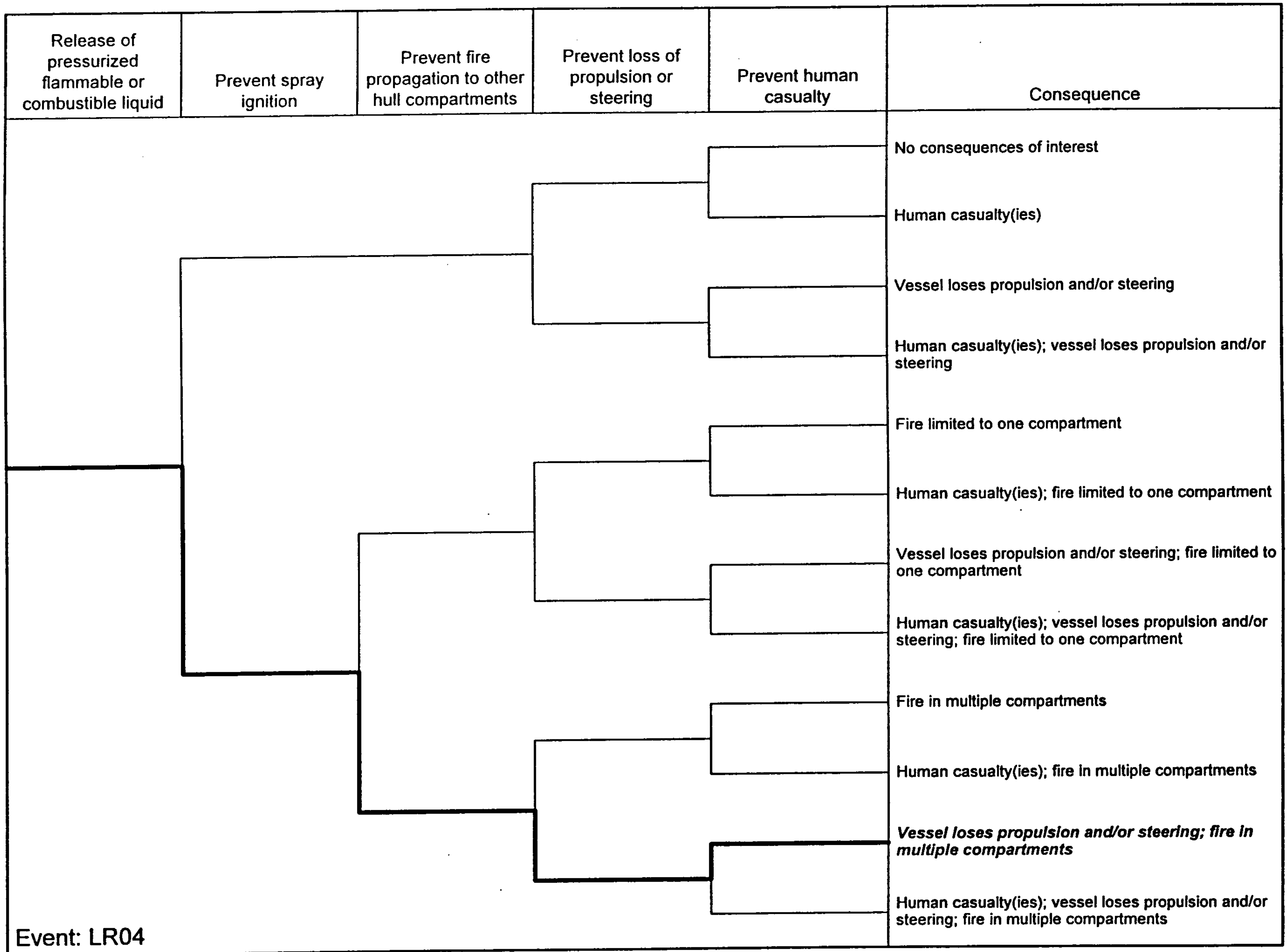
LR Number: 5353660 Degree of Severity: T

EXTENSIVELY DAMAGED BY FIRE OFF ORYUKDO, NEAR BUSAN, ON 14/4/82; SUBSEQUENTLY TOWED TO BUSAN, SOLD AND BROKEN UP.

REPORTED THAT FUEL OIL FROM AIR VENT PIPE CONNECTED TO MAIN ENGINE SERVICE TANK LEAKED ONTO NO. 2 CYLINDER HEAD COVER AND EXHAUST MANIFOLD OF THE MAIN ENGINE, CAUSING THE FIRE. ARRIVED BUSAN OUTER HARBOUR IN TOW OF FOUR TUGS. HULL, MACHINERY AND EQUIPMENT WERE EXTENSIVELY DAMAGED AND LOCAL HULL UNDERWRITERS ACCEPTED VESSEL AS A CONSTRUCTIVE TOTAL LOSS. BREAKING COMMENCED 1/7/82 AT BUSAN, AND WAS COMPLETED 23/7/82.

Event Number: 5353660 (LR04)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Fuel oil from the air vent pipe connected to the main engine service tank leaked onto the No. 2 cylinder head cover and exhaust manifold	
Ignition Source	Hot surface (cylinder head cover and exhaust manifold of the main engine)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was sold for dismantling	Not inferred



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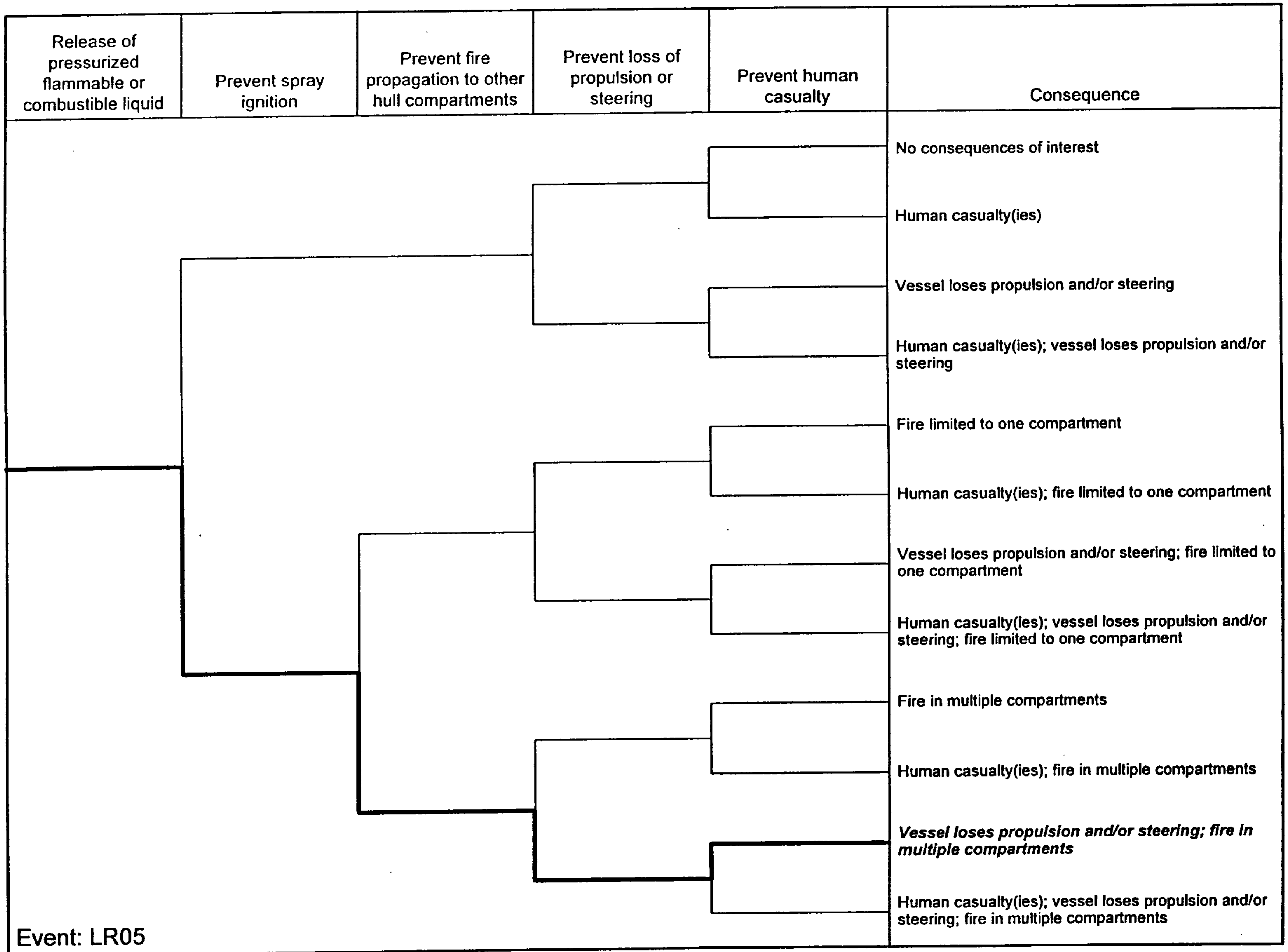
LR Number: 5368378 Degree of Severity: T

SANK AFTER EXPLOSION AND FLOODING IN ER N.W. OF BENGHAZI IN LAT.33 22 15N., LONG.18 06 35E. ON 5/5/78.

Event Number: 5368378 (LR05)	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil or lube oil/engine room	
Cause	The report says "explosion and flooding in the engine room," but no additional details are provided	Boiler explosion
Ignition Source	Not stated	Boiler explosion
Detection	Not stated	Not inferred
Release Isolation		Unsuccessful
Fire Suppression		Unsuccessful
Impact on Propulsion	Loss of propulsion (the vessel sank)	
Impact on Steering	Loss of steering (the vessel sank)	
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel sank	Not inferred



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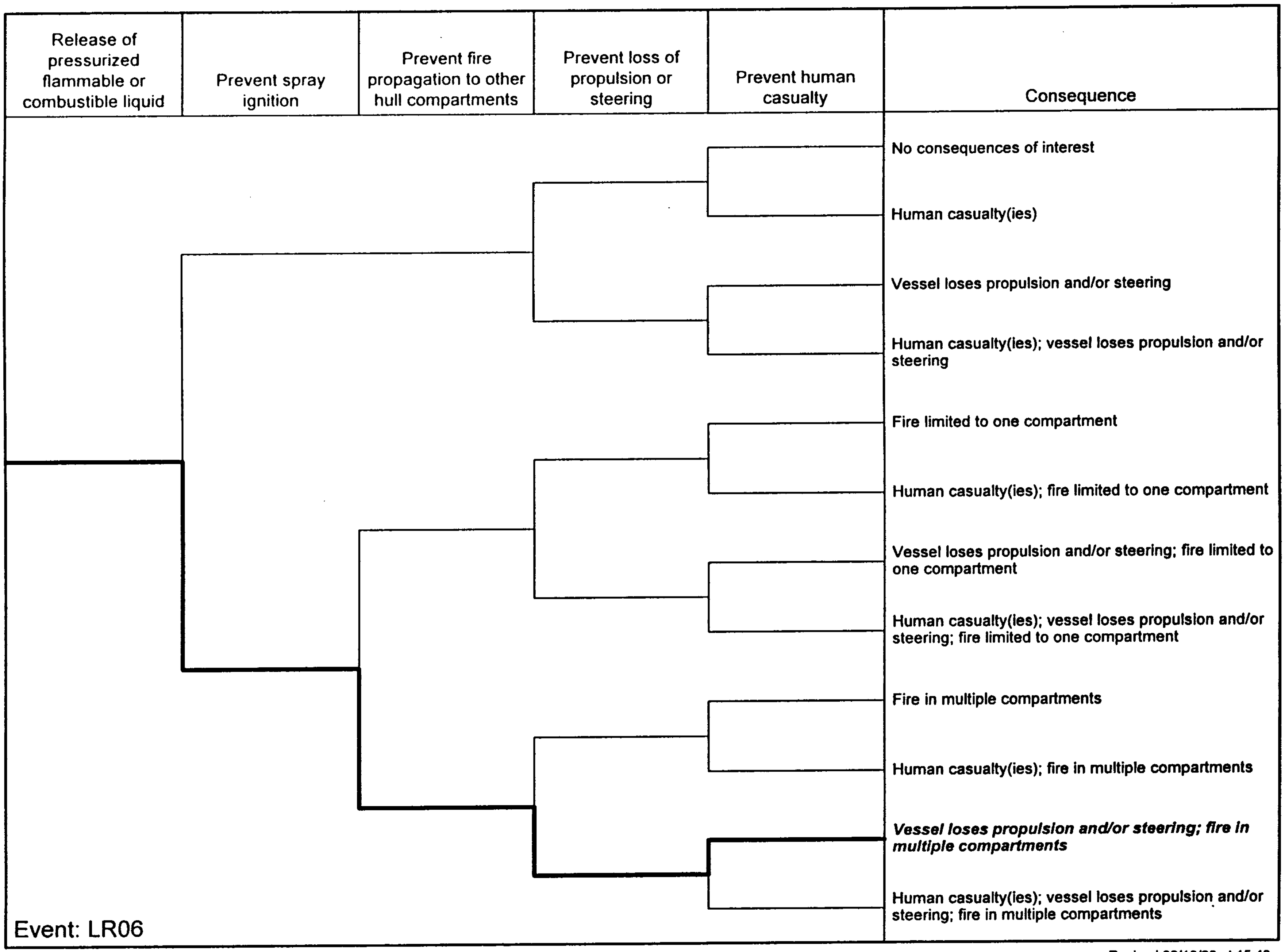
LR Number: 5381875 Degree of Severity: T

EXTENSIVELY DAMAGED BY FIRE IN E.R. IN RED SEA ON 20/5/81; TOWED TO SUEZ AND BEACHED; REFLOATED AND TOWED TO KARACHIFOR BREAKING UP; SUBSEQUENTLY STRANDED OFF MANORA ON 2/7/89 AFTER DRAGGING ANCHORS IN HEAVY WEATHER.

E.R. FIRE CAUSED BY A BURST FUEL PIPE SPRAYING OVER EXHAUST MANIFOLD WHICH SPREAD TO NO'S 2 & 3 HOLDS & ACCOMMODATION. VESSEL STRANDED UNDER THE NAME 'FARIDA II, 'UAE' FLAG AND SUBSEQUENTLY BROKEN UP 'IN SITU'.

Event Number: 5381875 (LR06)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Bursted fuel oil pipe spraying over exhaust manifold	
Ignition Source	Hot surface (exhaust manifold)	
Detection	Not stated	Not inferred
Release Isolation		Unsuccessful
Fire Suppression		Unsuccessful
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred



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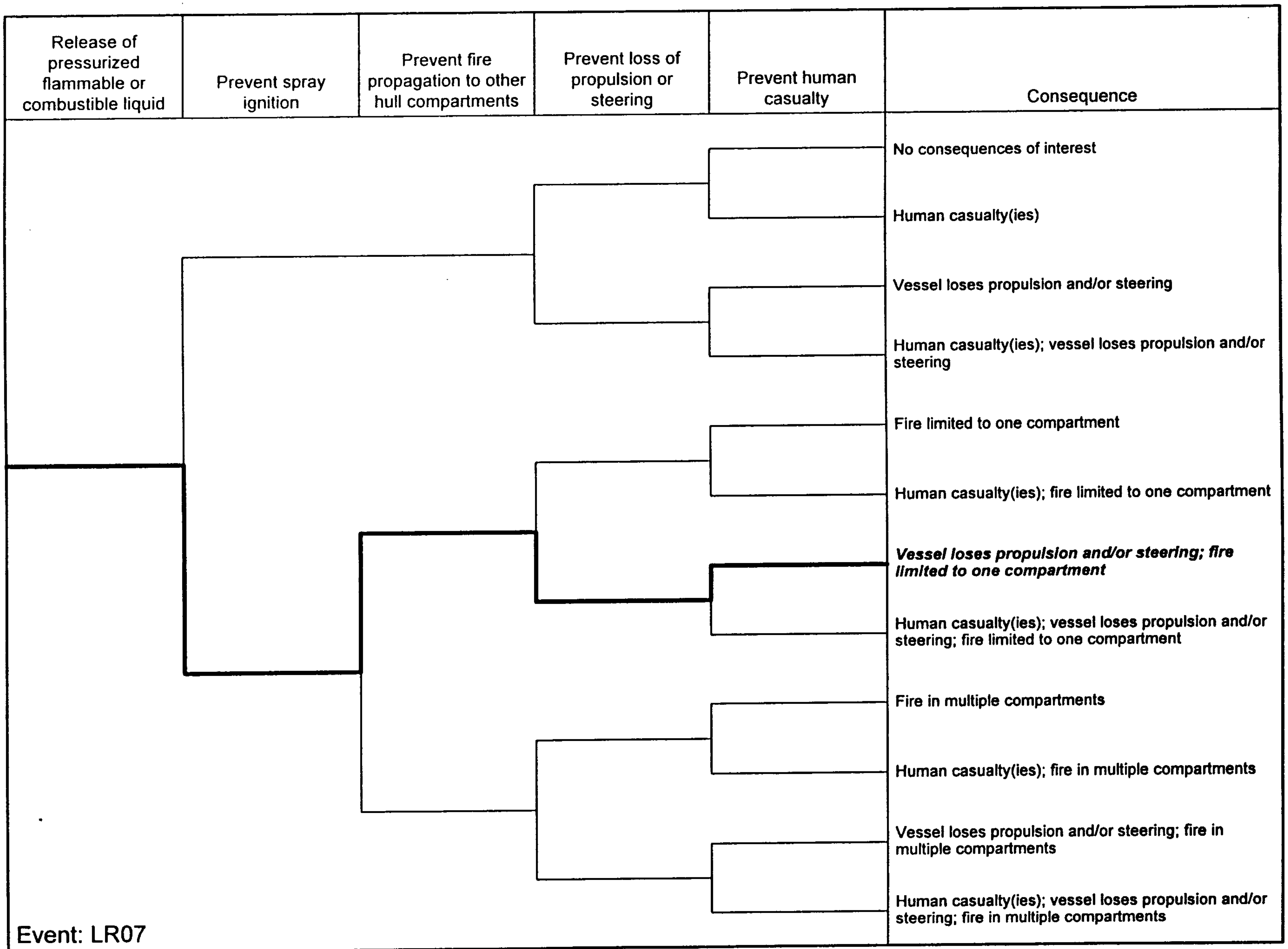
LR Number: 6411902 Degree of Severity: S

SUSTAINED EXPLOSION IN LUBE OIL PUMP 5 MILES OFF CORSICA ON 24/2/80, TAKEN IN TOW THE NEXT DAY. LATER TRADING. TOWED TO AJACCIO.

Event Number: 6411902 (LR07)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Explosion in lube oil pump (no details provided)	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was later traded (possibly for dismantling)	Not inferred



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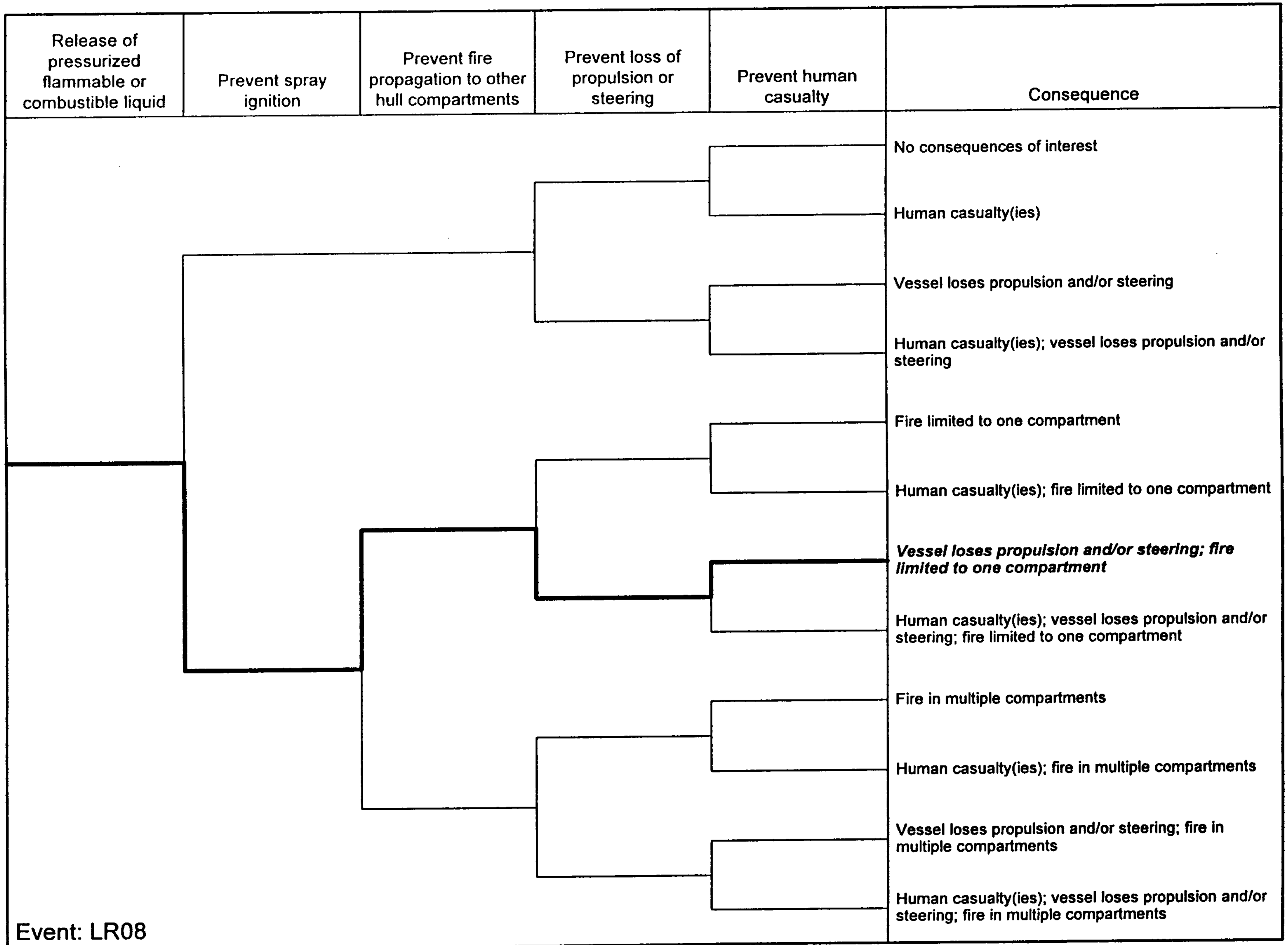
LR Number: 6416158 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM WHILE BUNKERING AT RAS TANURA ON 9/7/73. TAKEN TO ANCHORAGE. SAILED 17/7/73 FOR JAPAN.

APPARENTLY OVERFLOWING OF DIESEL BUNKER TANK AT SOUNDING PIPE. FIRE BROKE OUT IN LOWER ENGINE ROOM (S). BILGE PUMP BADLY DAMAGED & ELECTRIC CABLES OVERHEAD BADLY BURNT.

Event Number: 6416158 (LR08)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Apparent overflow of diesel banker at sounding pipe	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion (electric cables were badly burnt)
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired at Anchorage	Not inferred



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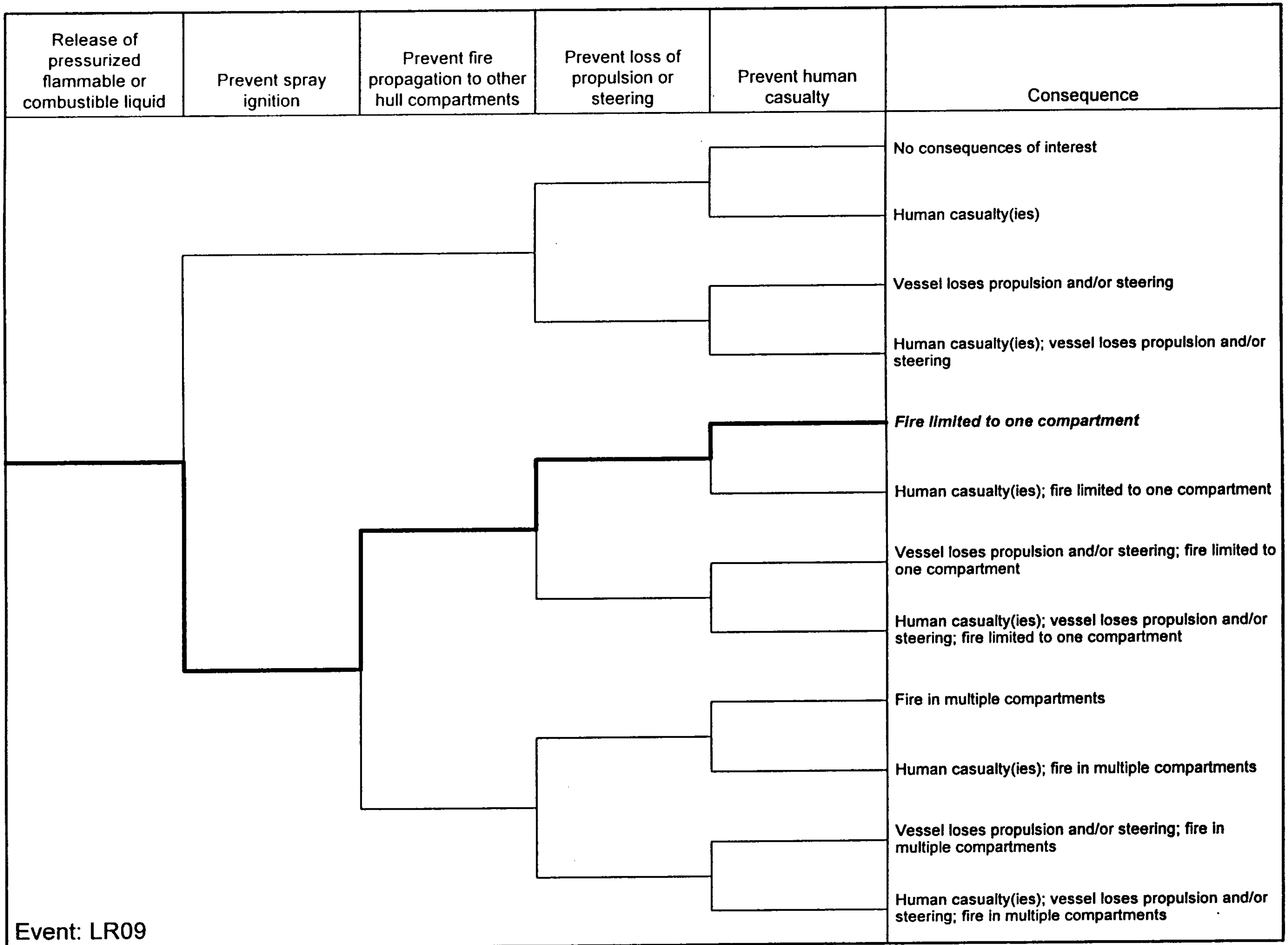
LR Number: 6420393 Degree of Severity: N

HAD FIRE WHILST ON VOYAGE MILFORD HAVEN TO SALT END ON 19/7/80 AFTER MAIN ENGINE FUEL PIPE FRACTURE. FIRE EXTINGUISHED IN 15 MINS. ARRIVED QUEEN'S DOCK, SWANSEA ON 20/7/80 FOR REPAIR; RESUMED SERVICE.

DAMAGE SUSTAINED TO SOME ELECTRICAL WIRING.

Event Number: 6420393 (LR09)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Engine fuel pipe fracture	
Ignition Source		Hot surface (exhaust manifold or exhaust pipe)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated, but fire was extinguished in 15 minutes	Not inferred
Impact on Propulsion		None
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – repaired at dock and resumed service	Not inferred



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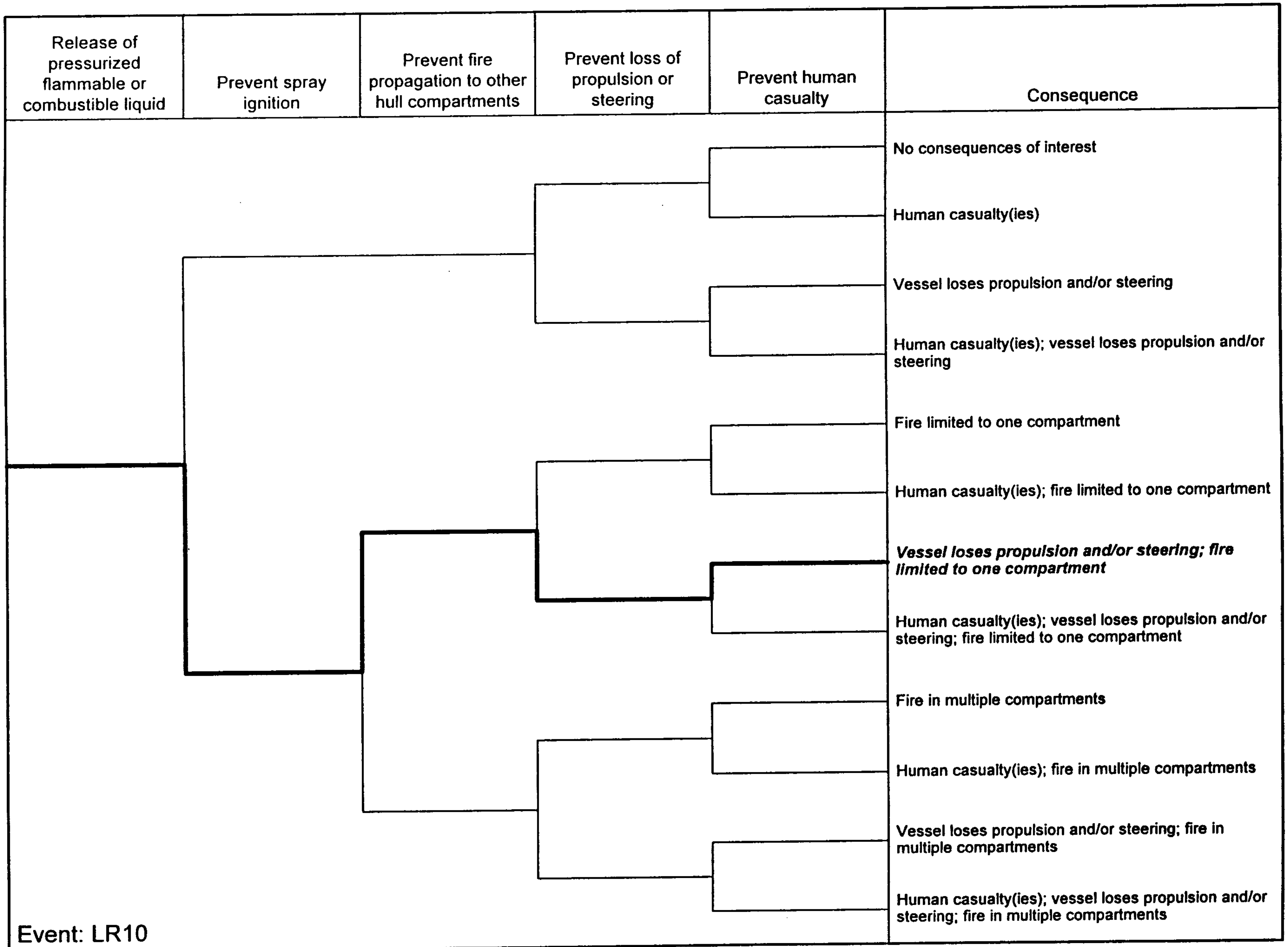
LR Number: 6811047 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM AND DRIFTED WHILE ON VOYAGE FOR BREAKING UP 220 MLS N.W. OF KUME ISLAND IN LAT.27 56N., LONG.123 06E., AT 2145 LT ON 15/4/81. FIRE EXTINGUISHED. TOWED TO KAOHSIUNG BY TUG 'SINEI MARU'.

ALLEGED CAUSE, THERMOMETER POCKET ON FORWARD LUBRICATING OIL COOLER OIL OUTLET BLEW OUT SPRAYING LUBRICATING OIL ONTO MAIN STEAM INLET TO HIGH PRESSURE TURBINE CAUSING OIL TO IGNITE.

Event Number: 6811047 (LR10)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Thermometer pocket on forward lubricating oil cooler blew out, spraying lube oil onto the main steam inlet to the high pressure turbine	
Ignition Source	Hot surface (turbine main steam outlet)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was on voyage for breaking up	Not inferred



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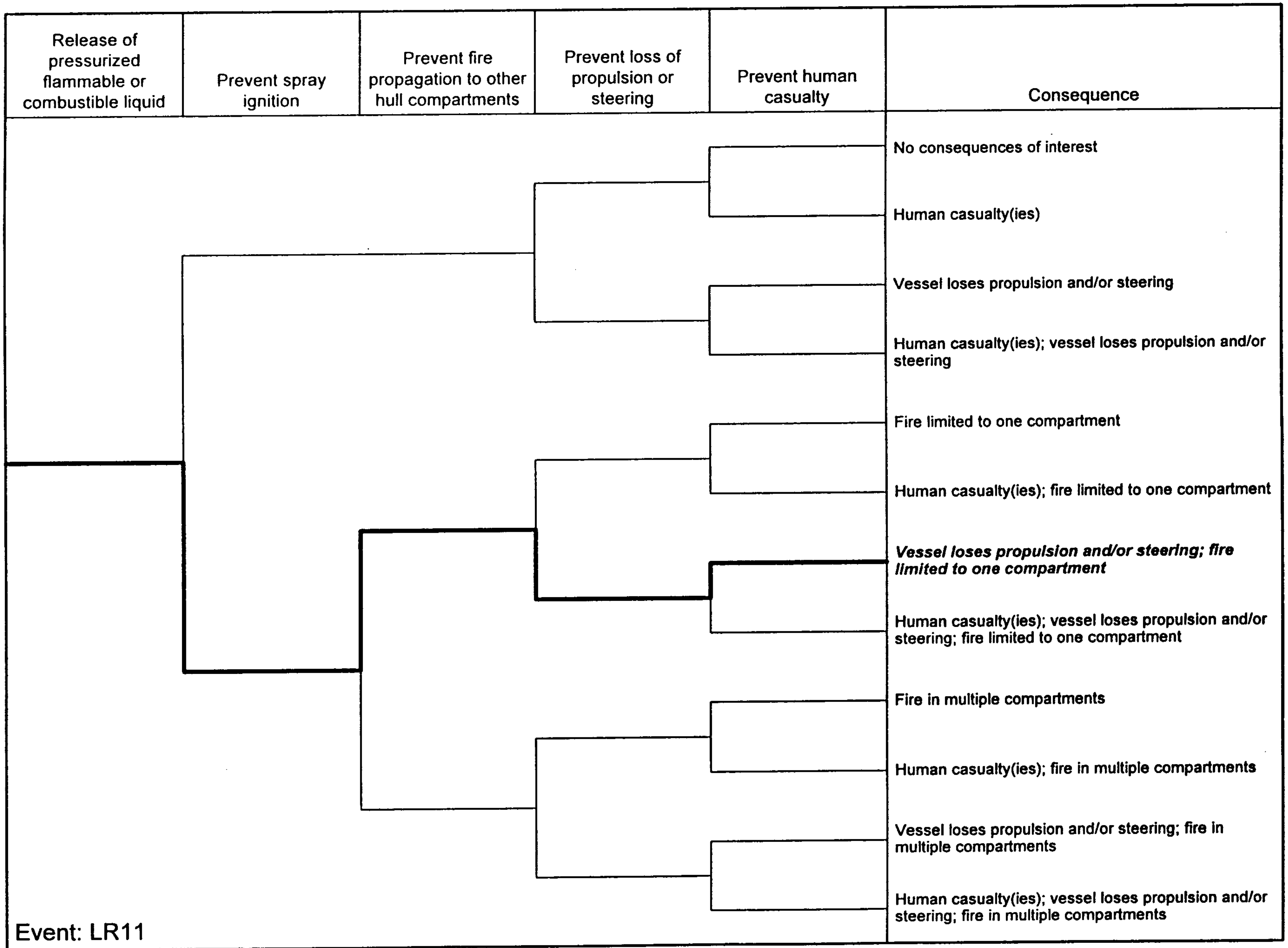
LR Number: 6814013 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM OFF PORT ELIZABETH ON 7/11/84 AFTER LEAKAGE OF OIL FROM MAIN FUEL SYSTEM, TAKEN IN TOW TO CAPE TOWN, WHERE ARRIVED 13/11/84. REPAIRED AND RETURNED TO SERVICE 30/11/84.

Event Number: 6814013 (LR11)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Leakage of oil from main fuel system	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired in Cape Town and returned to service	Not inferred



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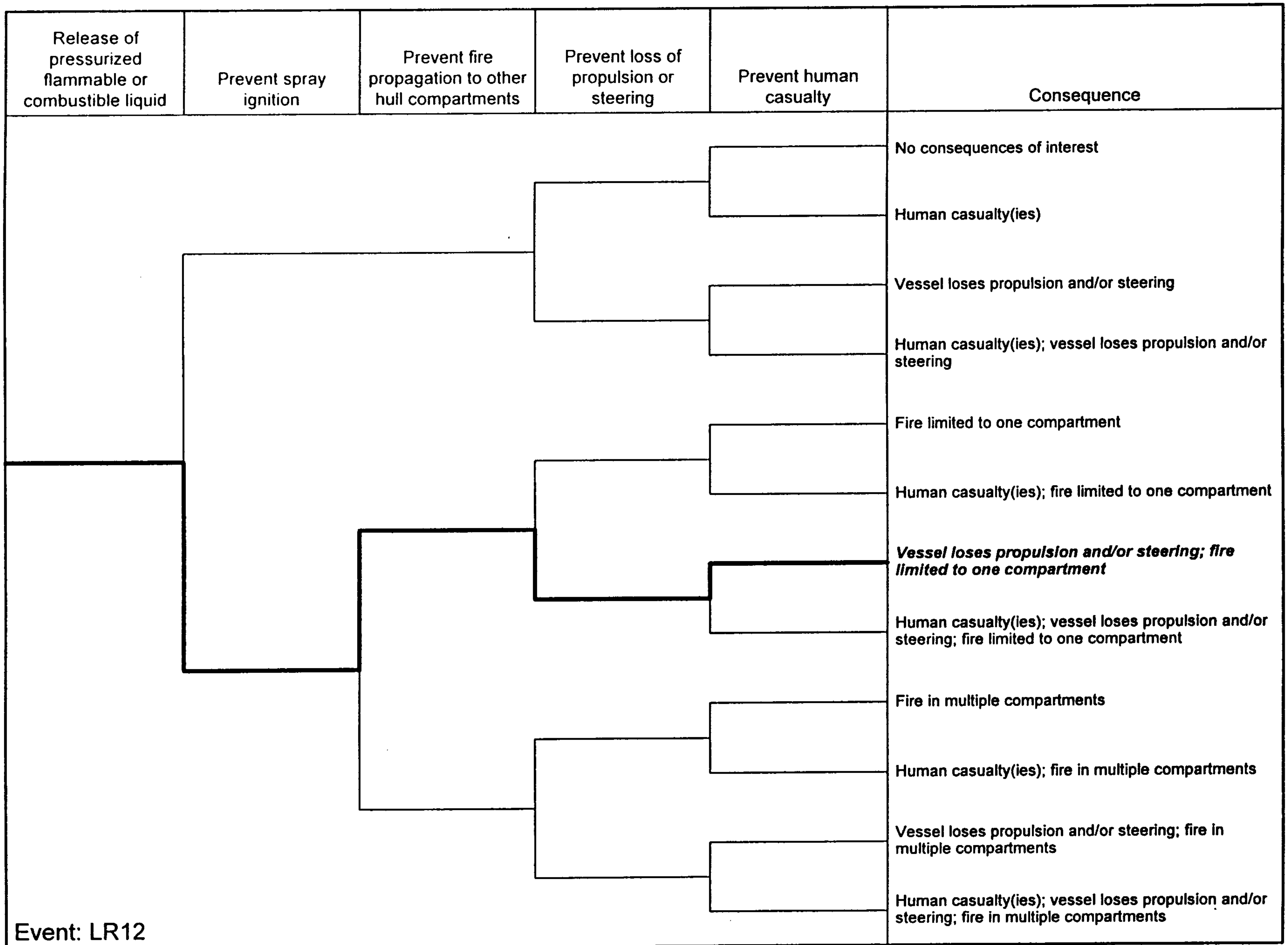
LR Number: 6822553 Degree of Severity: S

CAUGHT FIRE AND ABANDONED BY CREW IN LAT. 36 23N., LONG. 18 50E., ON 9/1/87. FIRE EXTINGUISHED AND VESSEL TOWED TO PIRAEUS. SOLD; SUBSEQUENTLY REPAIRED AND RETURNED TO SERVICE.

ALL 11 CREW RESCUED.

Event Number: 6822553 (LR12)	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was sold, subsequently repaired, and returned to service	Not inferred

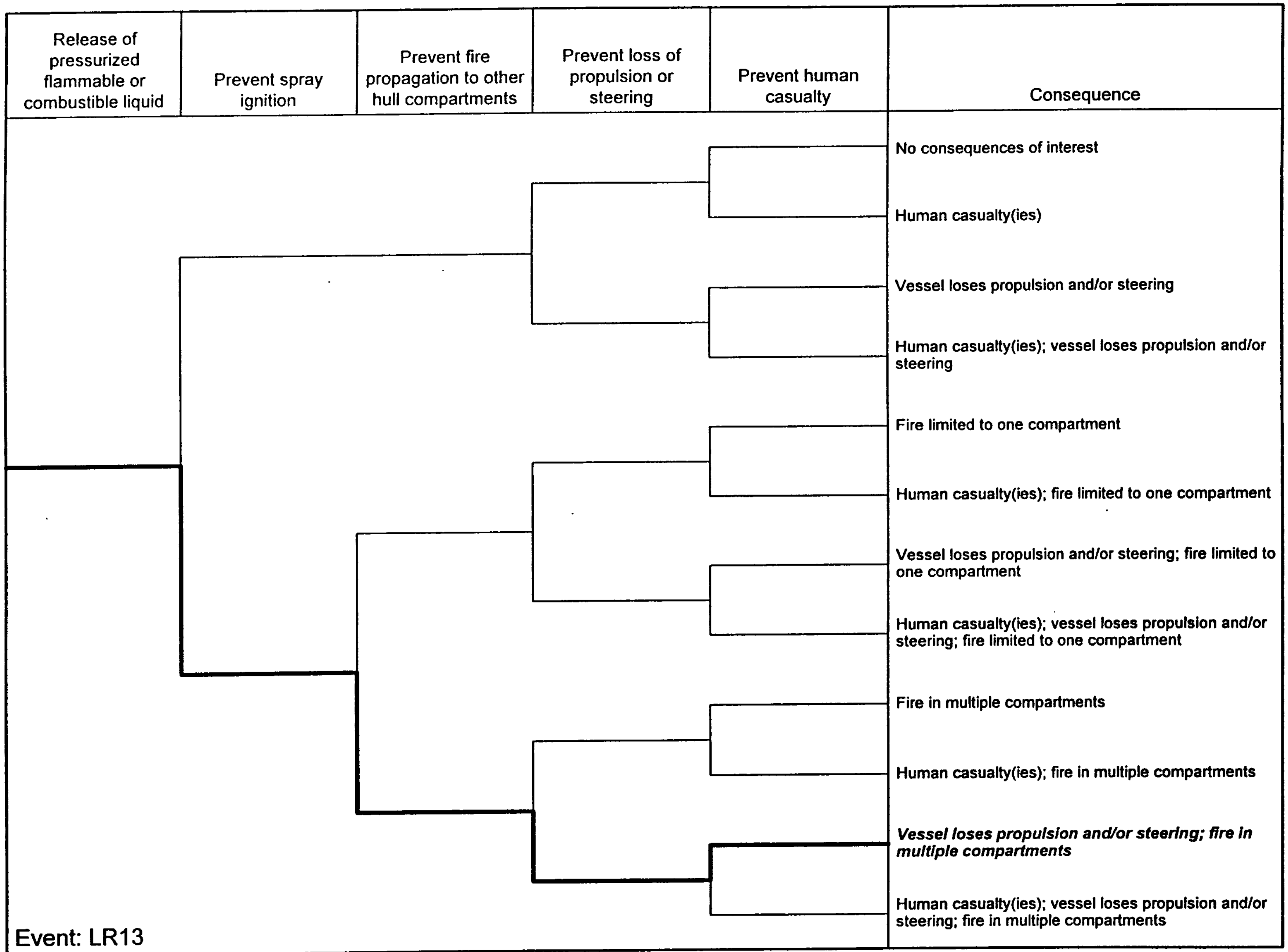


Revised 02/19/98 at 15:49

LR Number: 6901787 Degree of Severity: T

DAMAGED BY FIRE IN ENGINE ROOM WHILST ON VOYAGE FROM SAN JUAN, P.R., TO NEW ORLEANS, LA. ON 12/10/86; SUBSEQUENTLY TOWED TO TAMPA, FL., AND THENCE TO CARTAGENA, COLOMBIA. SOLD AND BROKEN UP.

Event Number: 6901787 (LR13)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was sold for dismantling	Not inferred



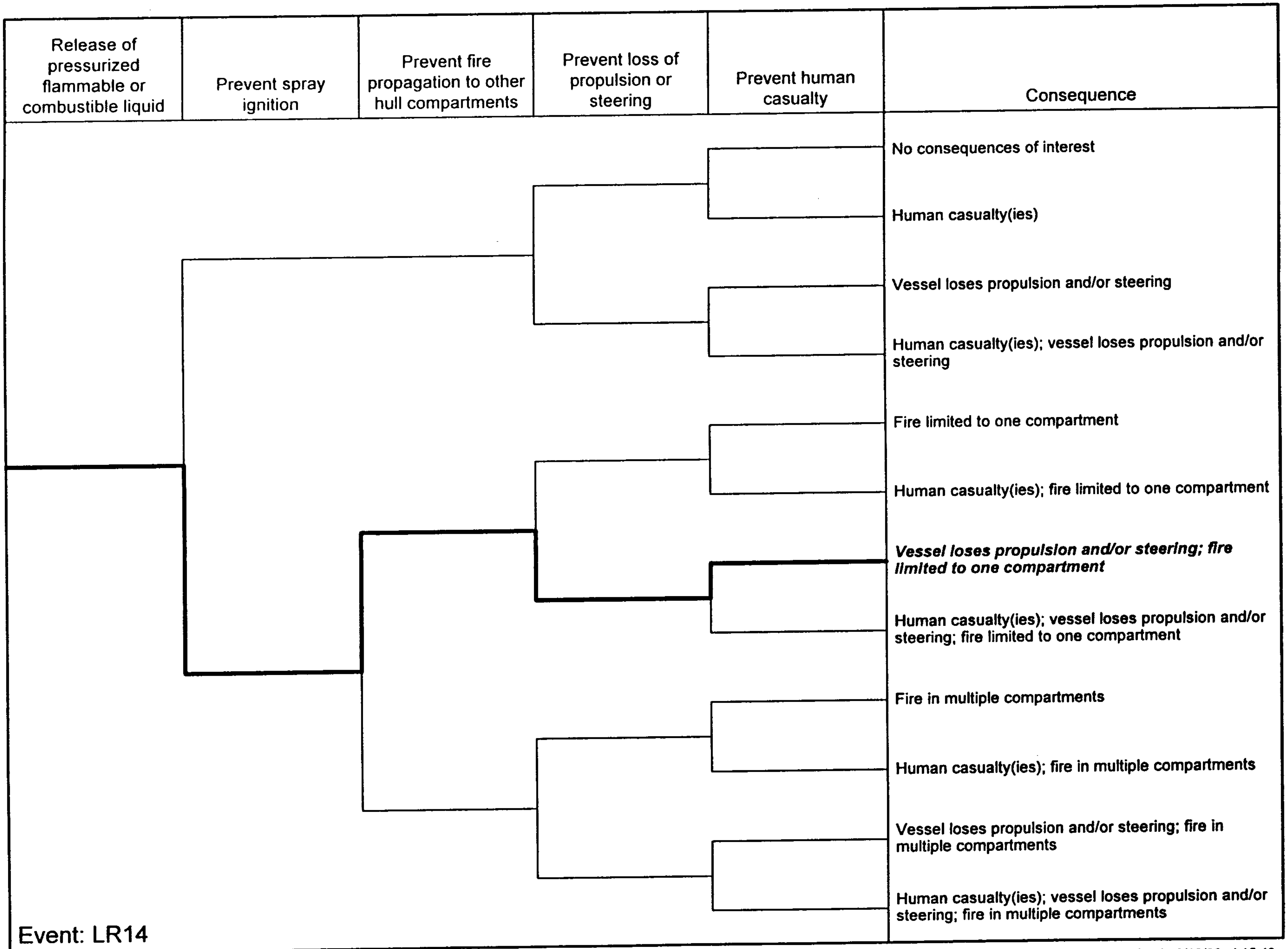
Revised 02/19/98 at 16:04

LR Number: 6909947 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM AT TENERIFE ON 3/12/81, DUE TOFUEL SPILLING ONTO GENERATORS; SUBSEQUENTLY REPAIRED AND RETURNED TO SERVICE. SAILED SANTANDER 2/2/82.

DAMAGED TURBO BLOWER AND AFFECTED MAIN ENGINE. SEVERE DAMAGE TO ELECTRICAL SYSTEM. EST. 20 DAYS REPAIRS.

Event Number: 6909947 (LR14)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Fuel spilled onto generators	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion (severe damage to the electrical system)
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired and returned to service	Not inferred

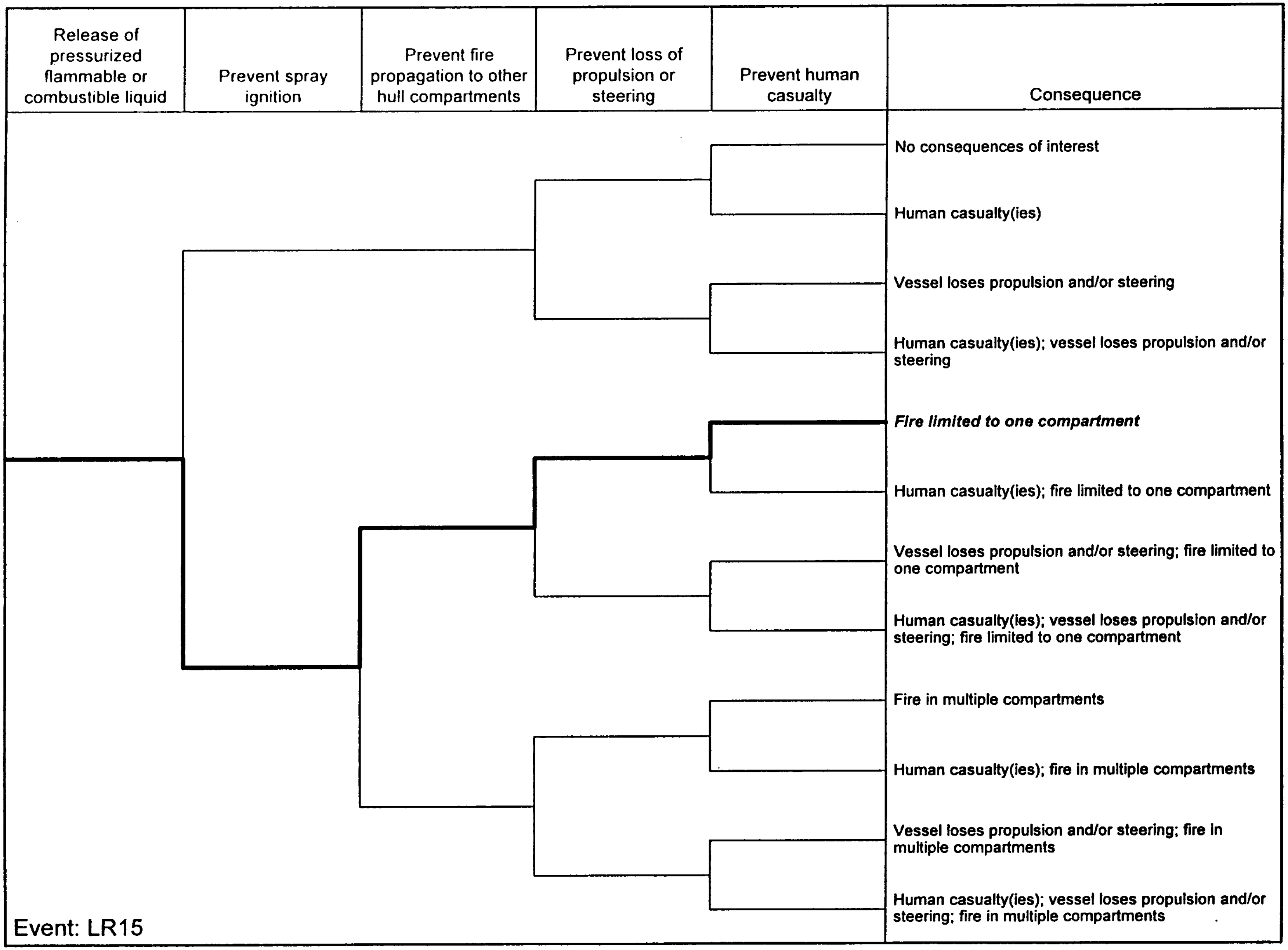


Revised 02/19/98 at 15:49

LR Number: 6923266 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM WHILST ON VOYAGE FROM CHILE TO NEWPORT AT 1424 GMT ON 24/3/82. PROCEEDED TO NEWPORT WHERE TEMPORARY REPAIRS EFFECTED. SAILED 9/4/82 FOR ROTTERDAM AND RESUMED TRADING. PERMANENT REPAIRS DEFERRED. SUSTAINED DAMAGE TO PORT SIDE MOTOR CABLES WHICH SEND DATA TO ENGINE INSTRUMENT CONTROL-ROOM. REPORTED CAUSE OF FIRE L.O. PRESSURE GAUGE PIPE FRACTURED.

Event Number: 6923266 (LR15)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Lube oil pressure gauge pipe fractured	
Ignition Source		Hot surface (exhaust manifold or exhaust pipe)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Not significant (the vessel proceeded to Newport for temporary repairs)
Impact on Steering		Not significant (the vessel proceeded to Newport for temporary repairs)
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – performed temporary repairs (permanent repairs were postponed)	Not inferred

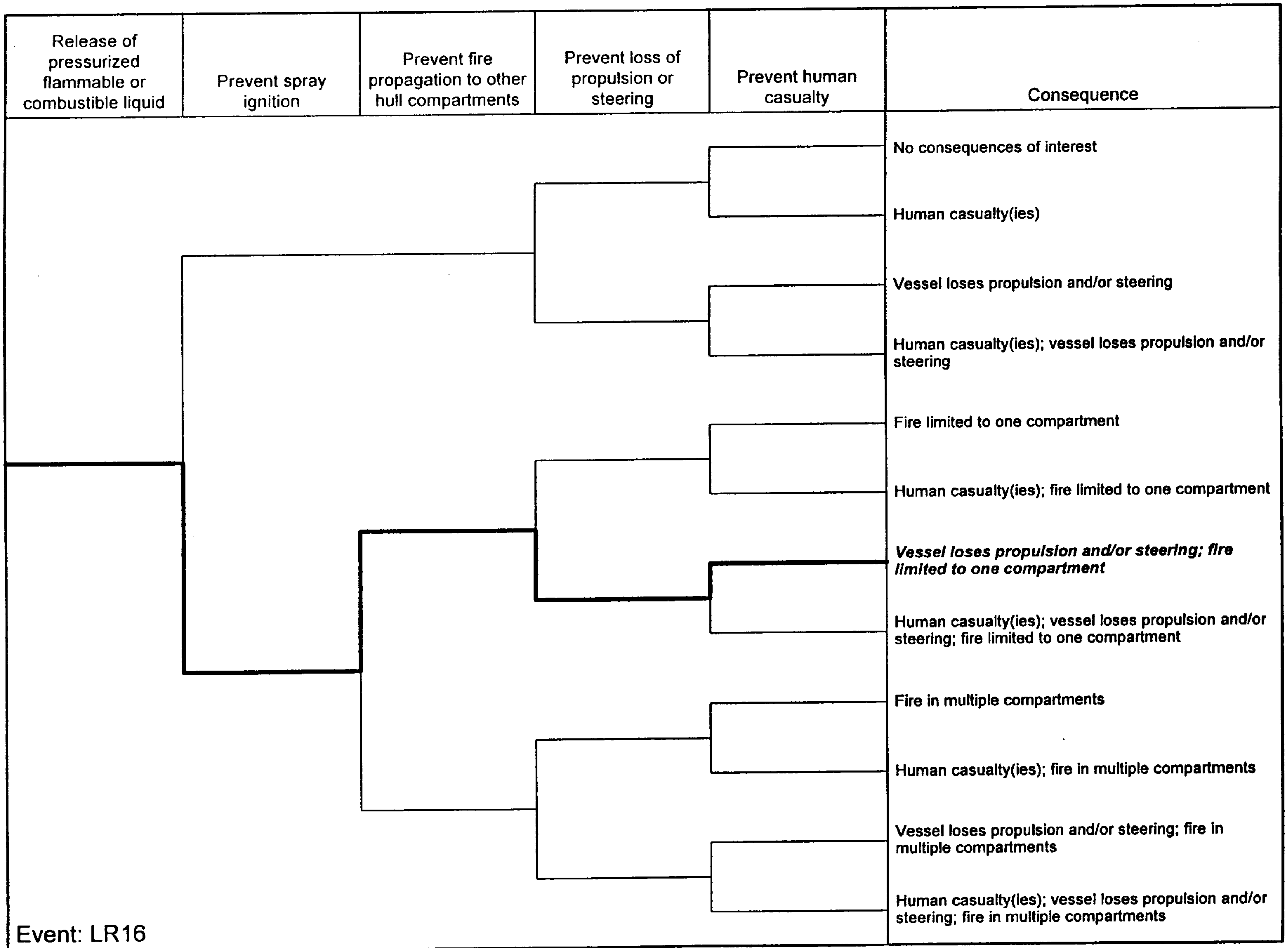


Revised 02/19/98 at 15:49

LR Number: 7004548 Degree of Severity: S

DAMAGED BY FIRE IN ENGINE ROOM IN LAT. 49 45N., LONG. 17242W., ON 2/11/81 IN HEAVY WEATHER; DRIFTED FOR 8 DAYS. TEMPORARY REPAIRS EFFECTED AND PROCEEDED UNDER TUG ESCORT TO VANCOUVER FOR PERMANENT REPAIRS. SAILED 15/12/81. 100 ELECTRIC CABLES RENEWED, MAIN SWITCHBOARD RECONDITIONED, DECK PLATE IN WAY CROPPED AND RENEWED, NOS. 2 AND 3 DIESEL ENGINES AND GENERATORS OPENED AND INSPECTED, ONE CRANKSHAFT RENEWED, FOUR ELECTRIC MOTORS OPENED; TESTED AND REPAIRED AND FIVE TRANSFORMERS CLEANED, TESTED AND REPAIRED.

Event Number: 7004548 (LR16)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel drifted for 8 days in heavy weather, and then had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired (renewed 100 electric cables, reconditioned the main switchboard, renewed deck plate, renewed diesel engines and generators, and so forth)	Not inferred



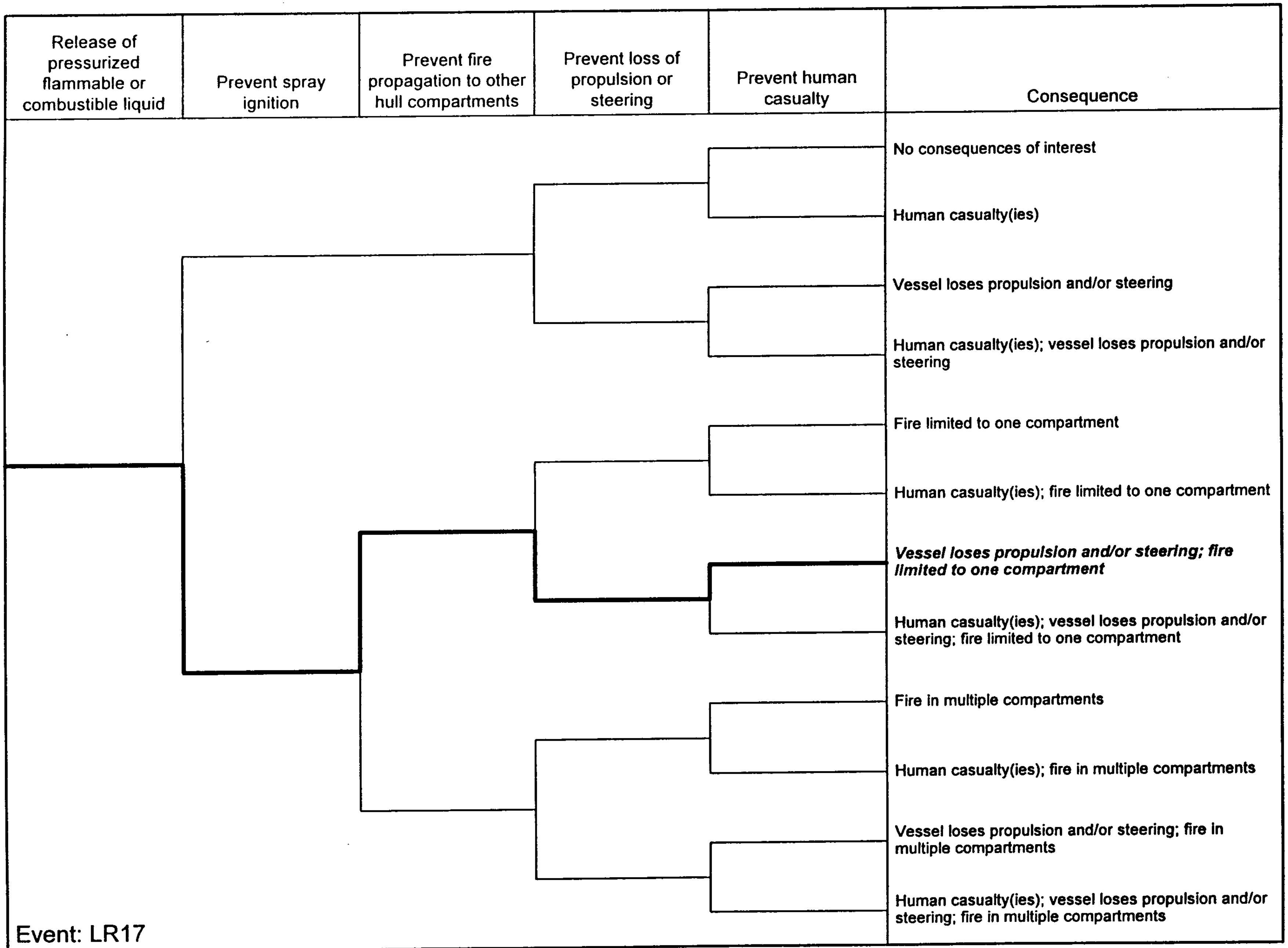
Revised 02/19/98 at 15:49

LR Number: 7015169 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM WHILE BUNKERING AT BARBERS POINT REFINERY, HONOLULU AT 2030 HRS 1/4/79. TOWED TO AIOI FOR REPAIRS. VESSEL SUBSEQUENTLY RESUMED SERVICE.

FIRE OCCURRED WHEN RECEIVING DIESEL OIL BUNKERS AND SPILL FROM OPEN SURROUNDING PIPE OCCURRED WHICH LOCATED BETWEEN TWO GENERATORS. ER & FITTINGS SERIOUSLY HEAT-AFFECTED AND(P) SHELL PLATING & FRAMES BUCKLED.

Event Number: 7015169 (LR17)	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Fuel oil/engine room	
Cause	Spill from open sounding pipe	
Ignition Source		Hot surface (exhaust manifold or exhaust pipe)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired and resumed service. The engine room fittings were seriously heat affected, and shell plating and frames were buckled	Not inferred



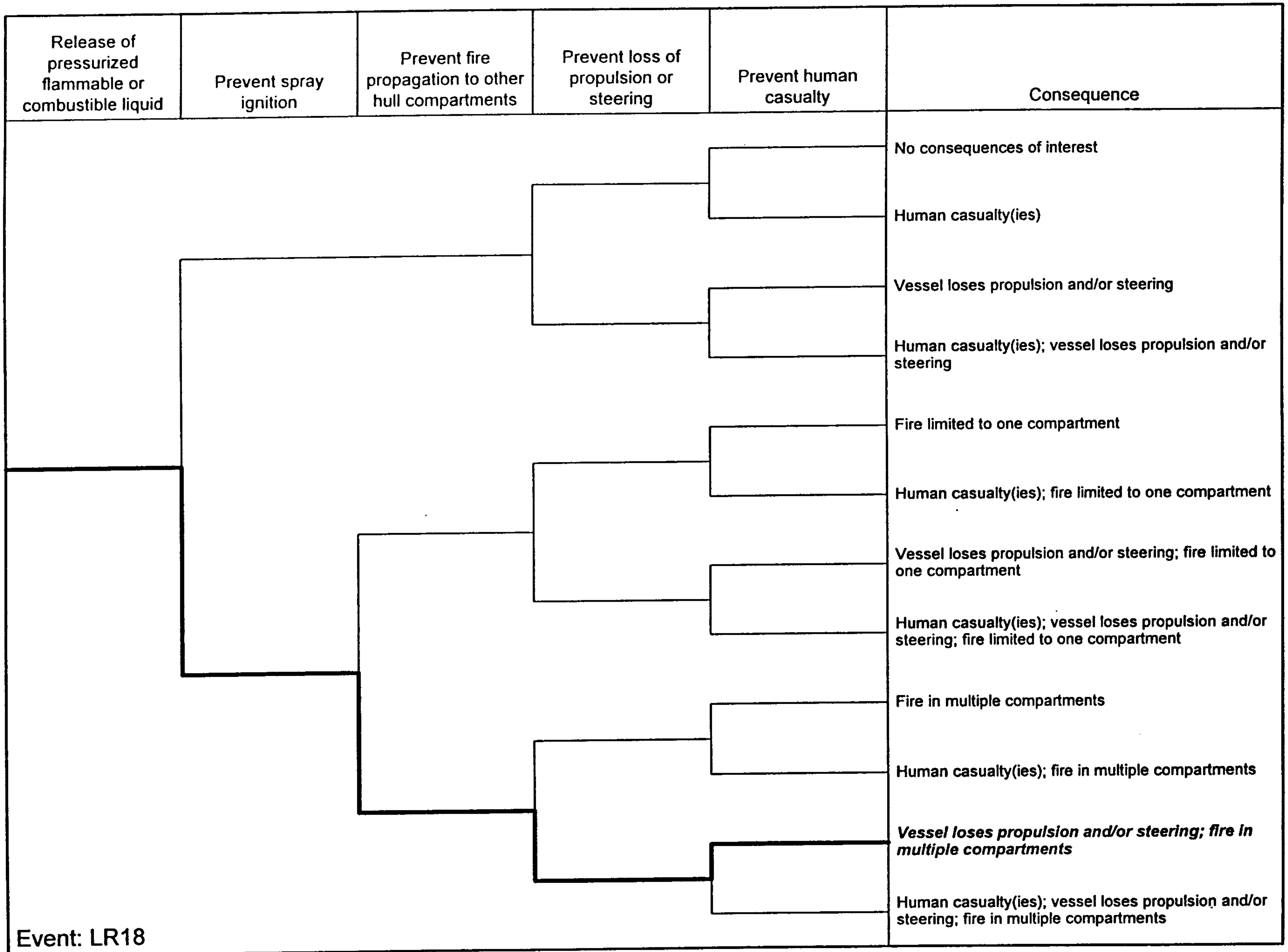
Revised 02/19/98 at 15:49

LR Number: 7036515 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM OFF MANILA ON 20/1/96 WHILST DREDGING. ARRIVED ALANG ON 11/3/97 FOR DEMOLITION.

REPORTED FIRE DUE TO A BROKEN FUEL LINE.

Event Number: 7036515 (LR18)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Broken fuel line	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion (the vessel was demolished)
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was demolished	Not inferred



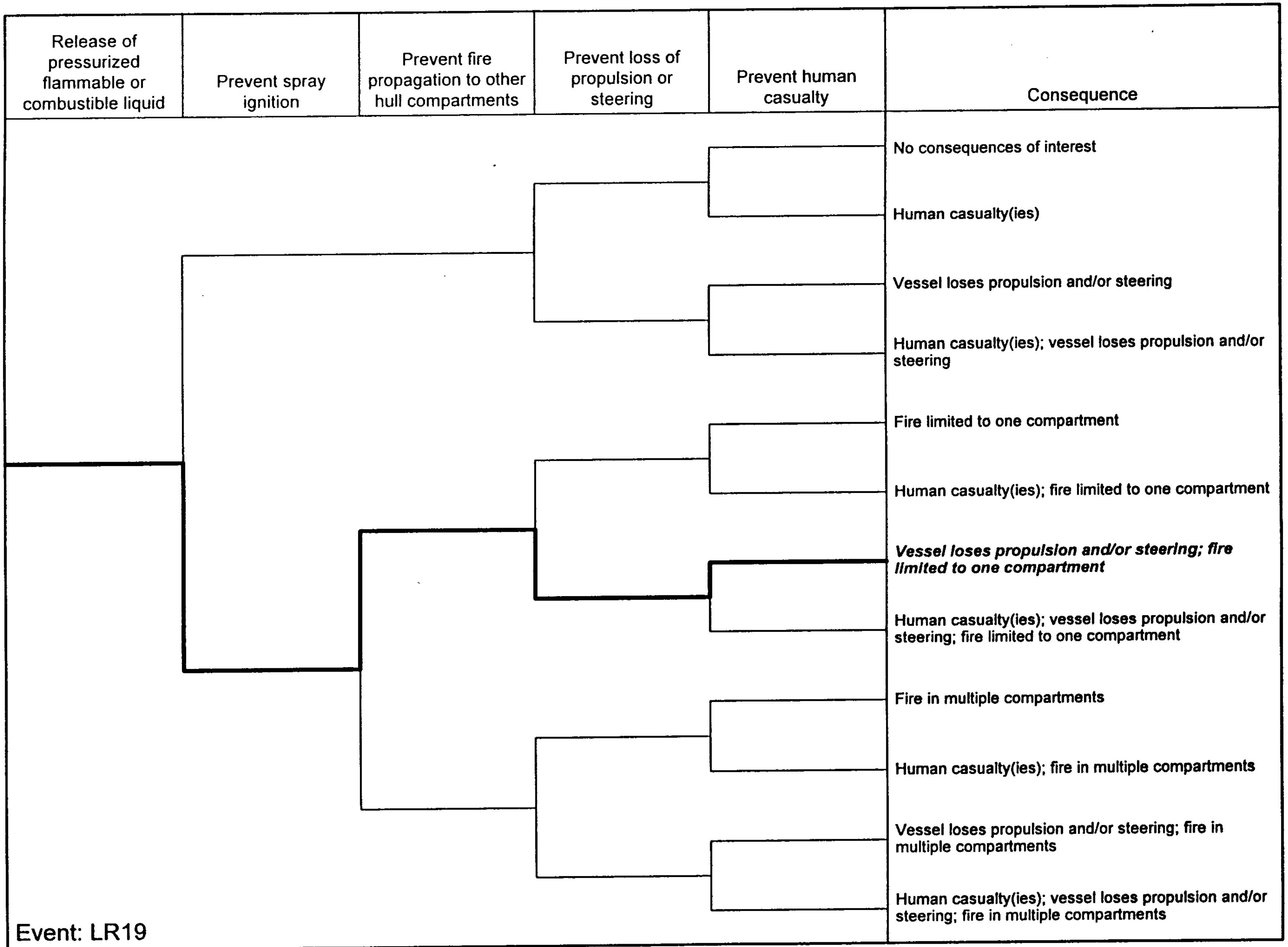
Revised 02/19/98 at 16:04

LR Number: 7107235 Degree of Severity: S

DAMAGED BY FIRE IN ENGINE ROOM WHILST ACTING AS A MOORING TUG FOR TANKERS AT PUERTO MIRANDA ON 20/3/82. REPAIRS EFFECTED AT MARACAIBO AND RESUMED SERVICE IN MARCH '83.

REPORTED CAUGHT FIRE DUE TO LEAKING FUEL FROM PORT MAIN ENGINE SYSTEM BACK PRESSURE VALVE. DETAILS OF DAMAGES NOT REPORTED.

Event Number: 7107235 (LR19)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	A back pressure valve on the port main engine system leaked fuel	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assume vessel lost propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired at Maracaibo and returned to service. The nature of damages was not reported	

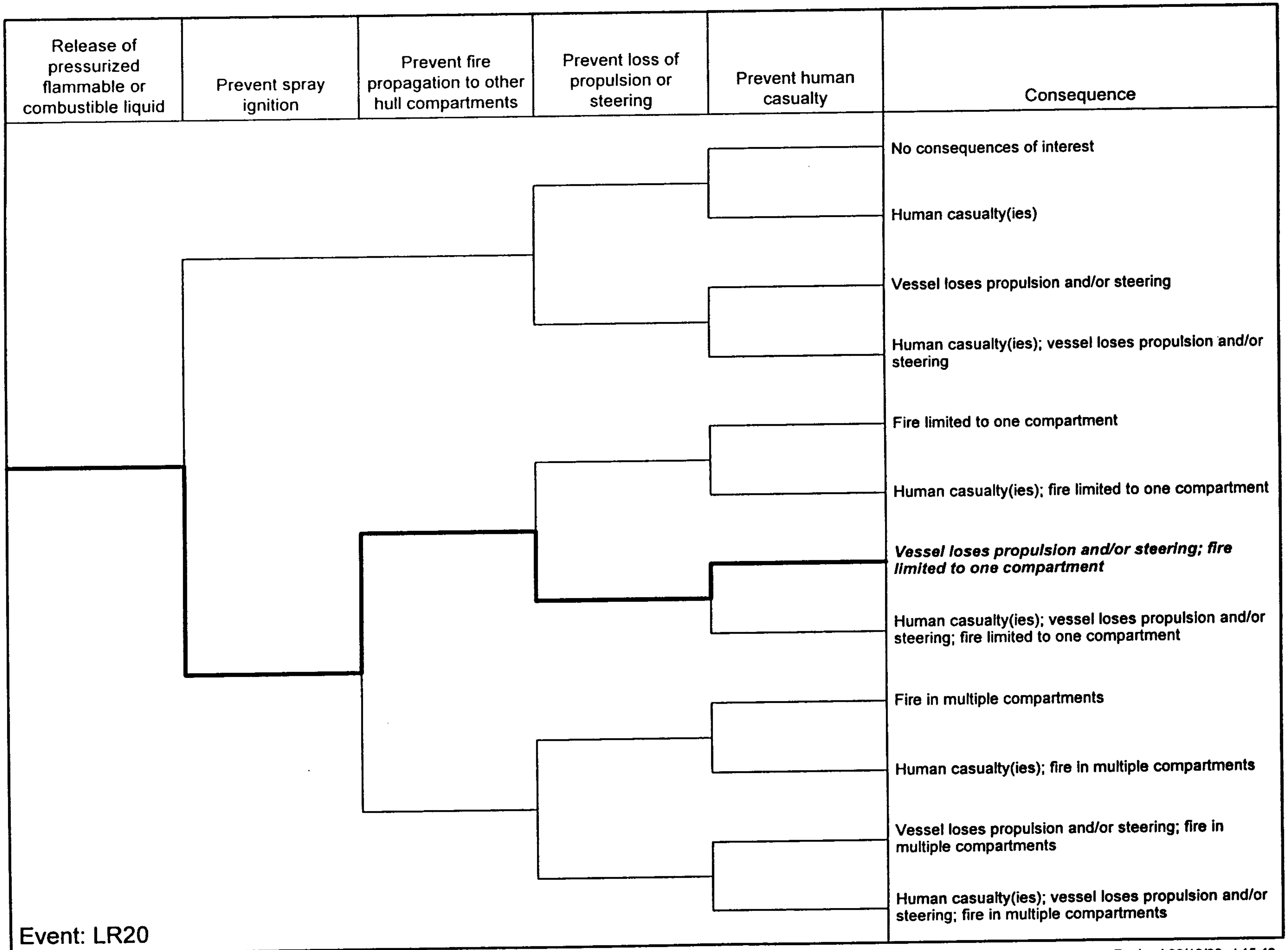


Revised 02/19/98 at 15:49

LR Number: 7234363 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM IN LAT. 61 09N., LONG. 00 20E., ON 6/4/79. TOWED TO BOLOGNE. SUBSEQUENTLY REPAIRED AT GDANSK.

Event Number: 7234363 (LR20)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired (no details provided)	



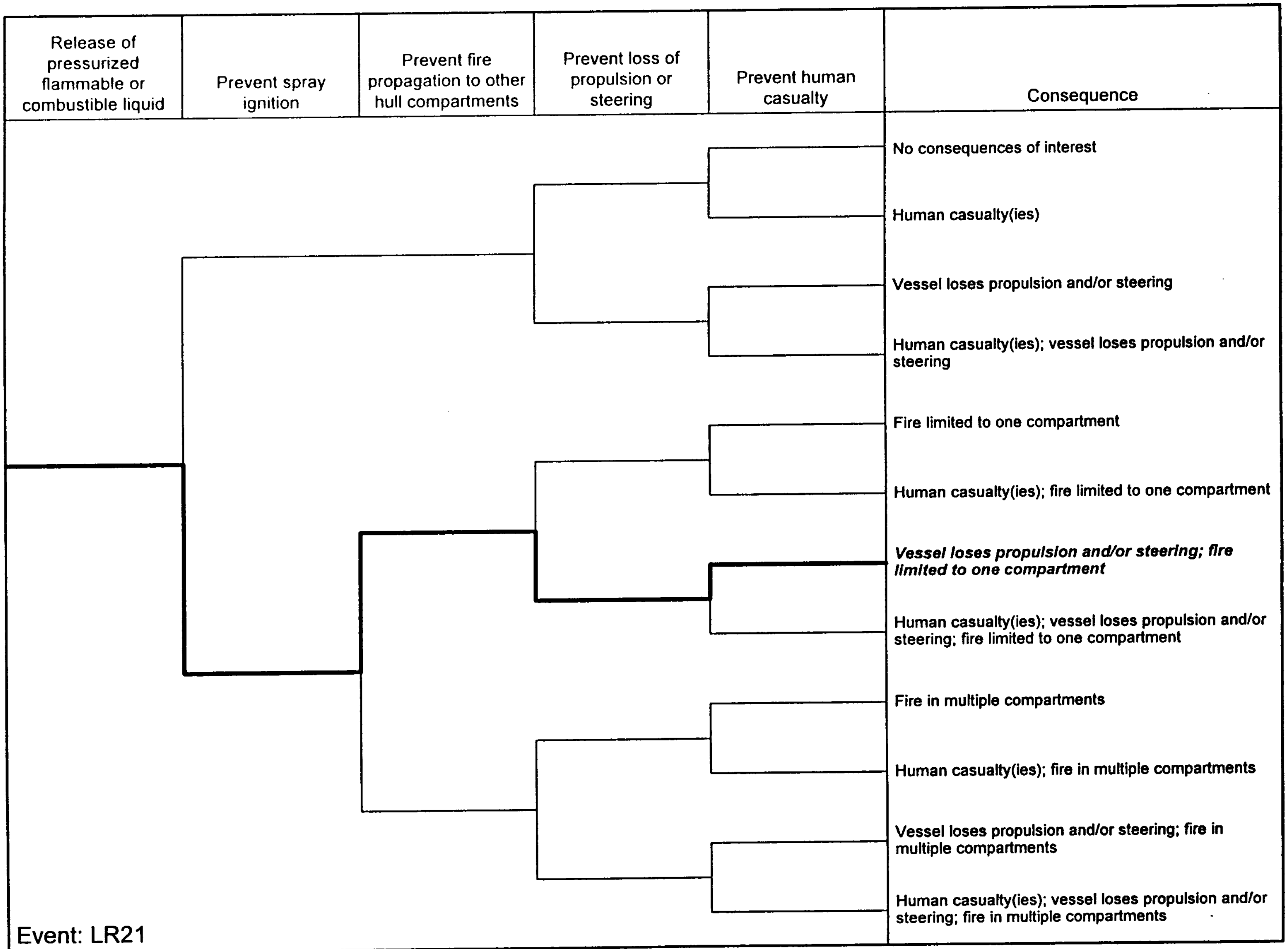
Revised 02/19/98 at 15:49

LR Number: 7324704 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM AFTER HYDRAULIC EXPLOSION IN LAT. 22 25N., LONG. 77 48W., ON 19/2/81. TOWED TO MIAMI WHERE REPAIRED AND VESSEL SAILED 1/10/82.

SUSTAINED L.O. FILTER FAILURE, ALLOWING HOT L.O. TO CATCH FIRE.

Event Number: 7324704 (LR21)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Lube oil filter failure, allowing hot oil to catch fire. Apparently the lube oil filter failed because of a hydraulic explosion	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired in Miami (no details provided)	



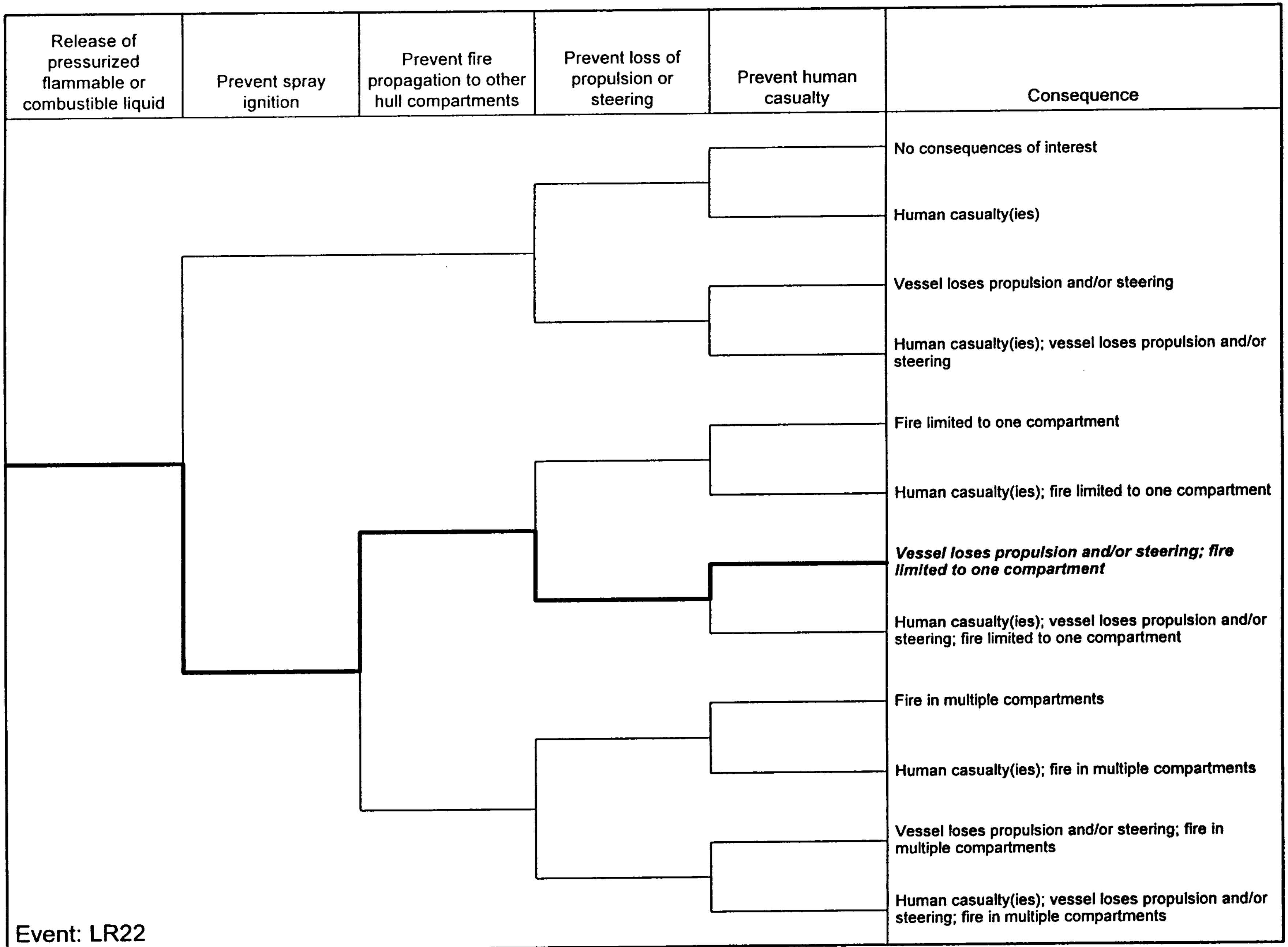
Revised 02/19/98 at 15:49

LR Number: 7340954 Degree of Severity: S

DAMAGED BY FIRE IN ENGINE ROOM 4 MILES S.W. OF PLADDA ON 27/10/82 IN HEAVY WEATHER, TAKEN IN TOW TO GLASGOW WHERE REPAIRED.

FIRE FIRST REPORTED AT 1641GMT AND EXTINGUISHED 1848GMT. VESSEL WITHOUT POWER AND WAS UNABLE TO USE ANCHOR AFTER RETURNING TO THE CLYDE.

Event Number: 7340954 (LR22)	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		Loss of steering (the vessel was without power)
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



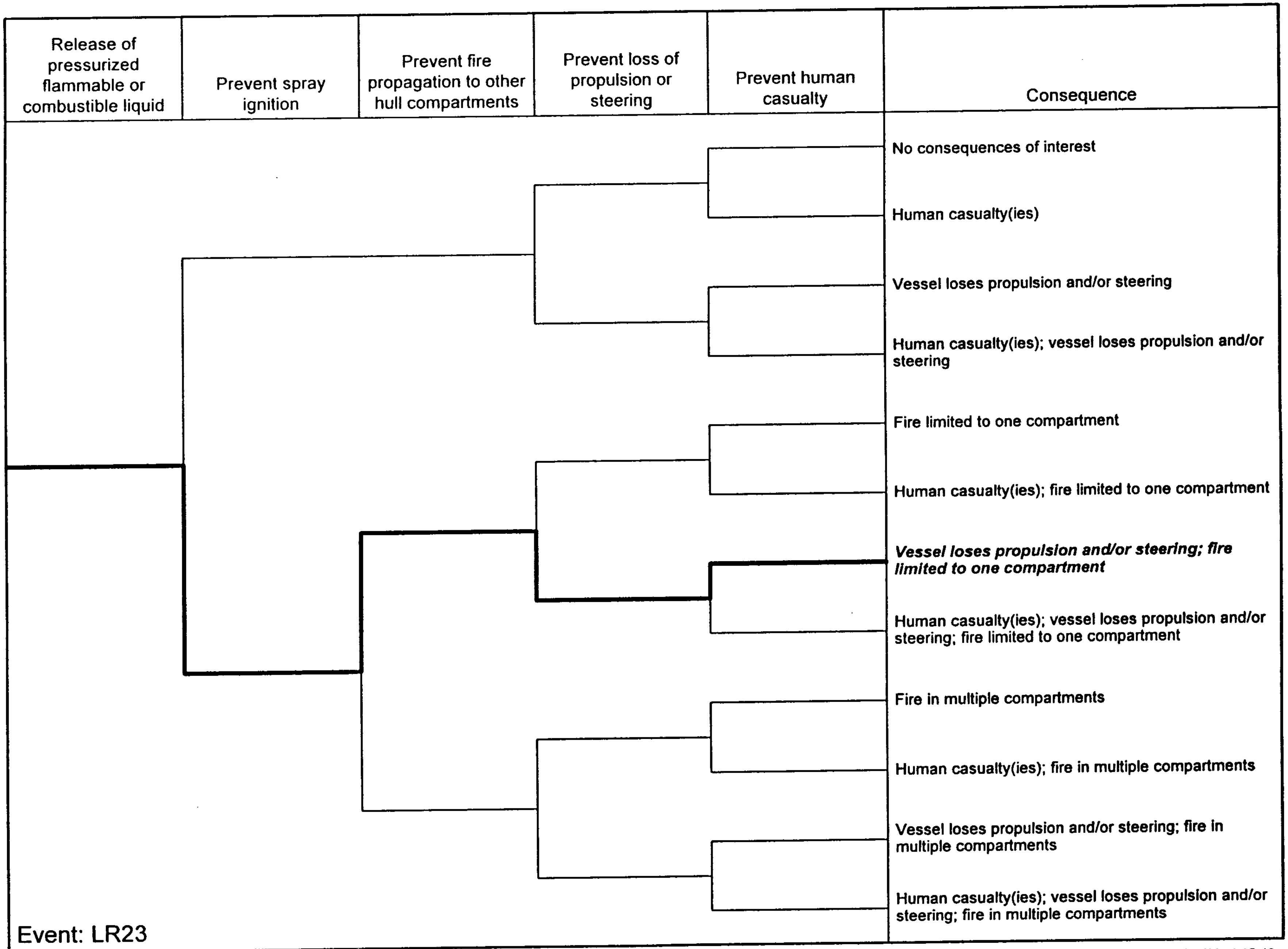
Revised 02/19/98 at 15:49

LR Number: 7342988 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM WHILST LOADING CARGO AT BLUFF, NEW ZEALAND ON 17/2/85, TEMPORARY REPAIRS EFFECTED, SAILED 28/2/85 FOR BANDAR ABBAS; SUBSEQUENTLY ARRIVED AUCKLAND 23/4/85 FOR FURTHER REPAIRS, SAILED 5/5/85 ON COMPLETION.

FIRE CAUSED BY LUBRICATING OIL SPRAYING ON EXHAUST MANIFOLD. NO 3 ALTERNATOR COMPLETELY BURNT, MAIN ENGINE FORWARD CHARGER AIR SUCTION FILTER ASSEMBLY MELTED, ALL AUTO CONTROLS FOR REEFER PLANTS CHARRED.

Event Number: 7342988 (LR23)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Lube oil sprayed on exhaust manifold	
Ignition Source	Hot surface (exhaust manifold)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	

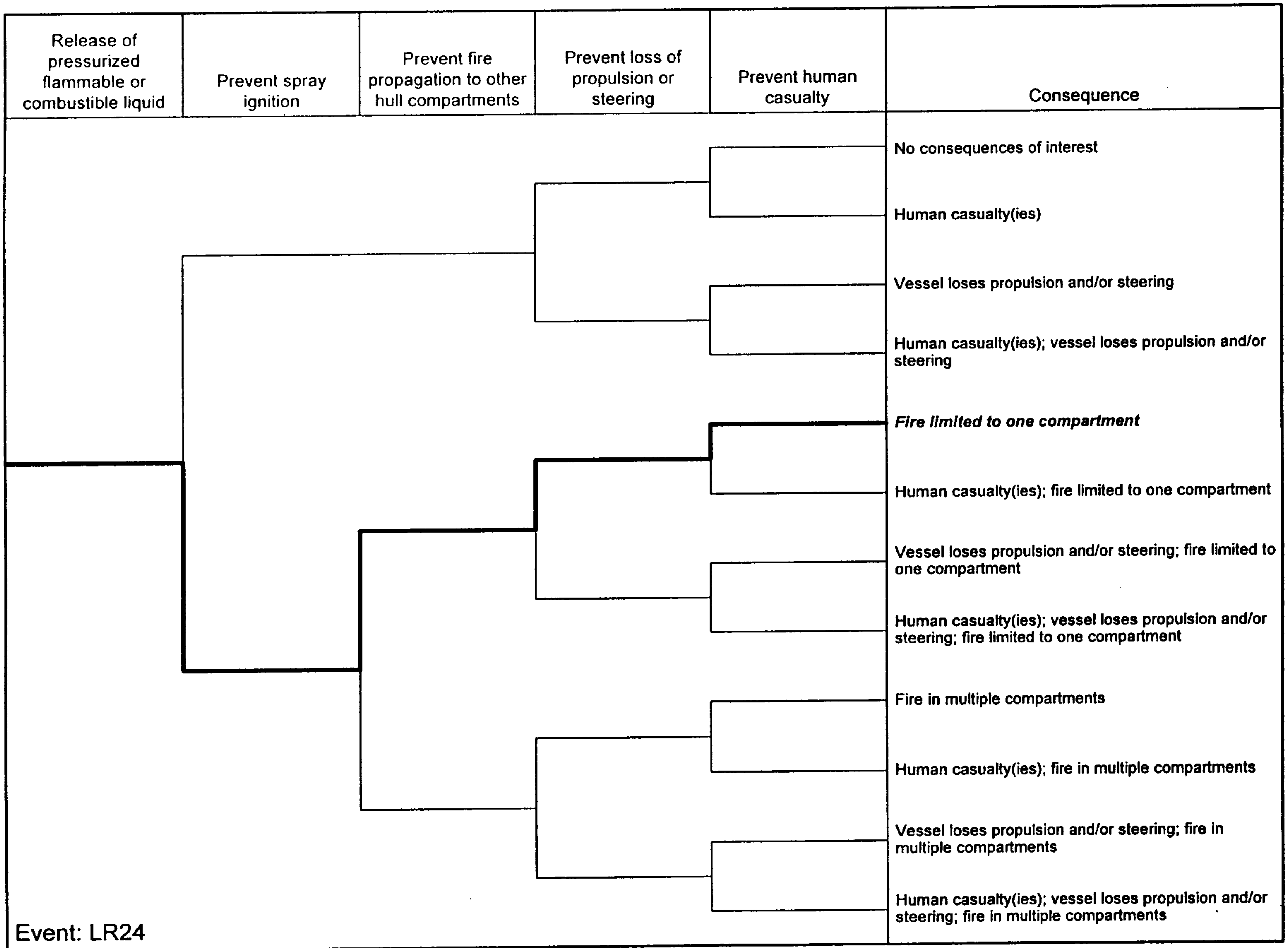


Revised 02/19/98 at 15:49

LR: 7373418 Degree of Severity: N

CAUGHT FIRE IN ENGINE ROOM IN CHESAPEAKE BAY, VA., ON 20/1/95 AFTER FUEL LEAK IN NO. 3 GENERATOR. FIRE EXTINGUISHED BY CREW. VESSEL ARRIVED BALTIMORE, MD., UNDER OWN POWER. SAILED 24/1/95.

Event Number: 7373418 (LR24)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Fuel leak in generator	
Ignition Source		Hot surface (exhaust manifold or exhaust pipe)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Crew	
Impact on Propulsion		Temporary loss of propulsion (vessel sailed under own power)
Impact on Steering		None (vessel sailed under own power)
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned	

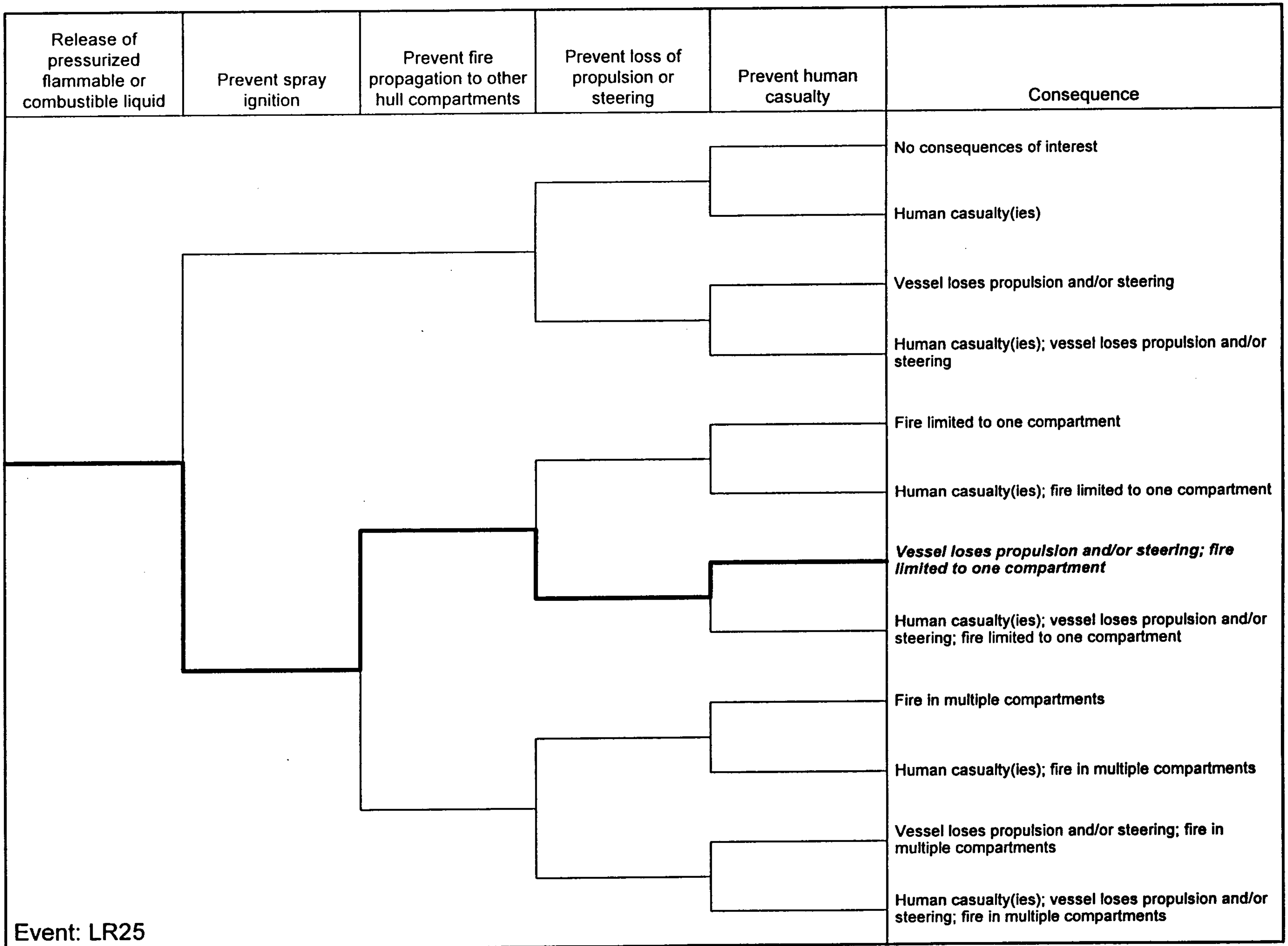


Revised 02/19/98 at 15:49

LR Number: 7382500 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM 17 MILES S.E. OF BEACHY HEAD, IN LAT. 50 40N., LONG. 00 40E., ON 15/10/94 AFTER FUEL LINE SPLIT. FIRE EXTINGUISHED AND VESSEL TOWED TO NEW HAVEN WHERE REPAIRS EFFECTED. RESUMED VOYAGE 24/10/94.

Event Number: 7382500 (LR25)	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Fuel line split	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	

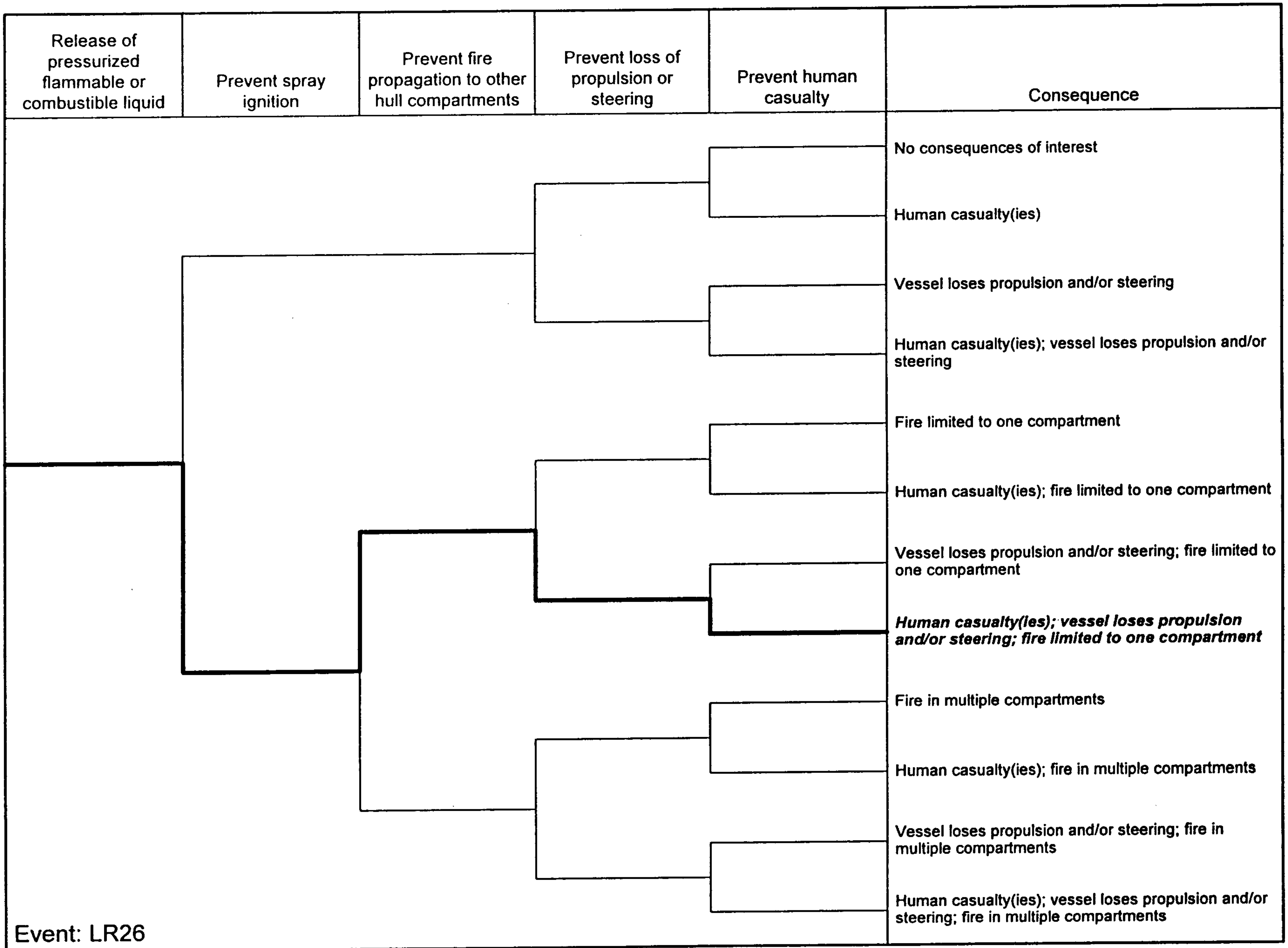


Revised 02/19/98 at 15:49

LR Number: 7385617 Degree of Severity: S

SUSTAINED EXPLOSION IN M.E. COOLING SYSTEM IN FLUSHING ROADS AT 0915LT., 14/3/87. LATER ANCHORED WITH TUG AID. REPAIR PRESUMED EFFECTED AS VESSEL RETURNED TO SERVICE ON 17/3/87.

Event Number: 7385617 (LR26)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Explosion in the main engine cooling system	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	One fatality	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



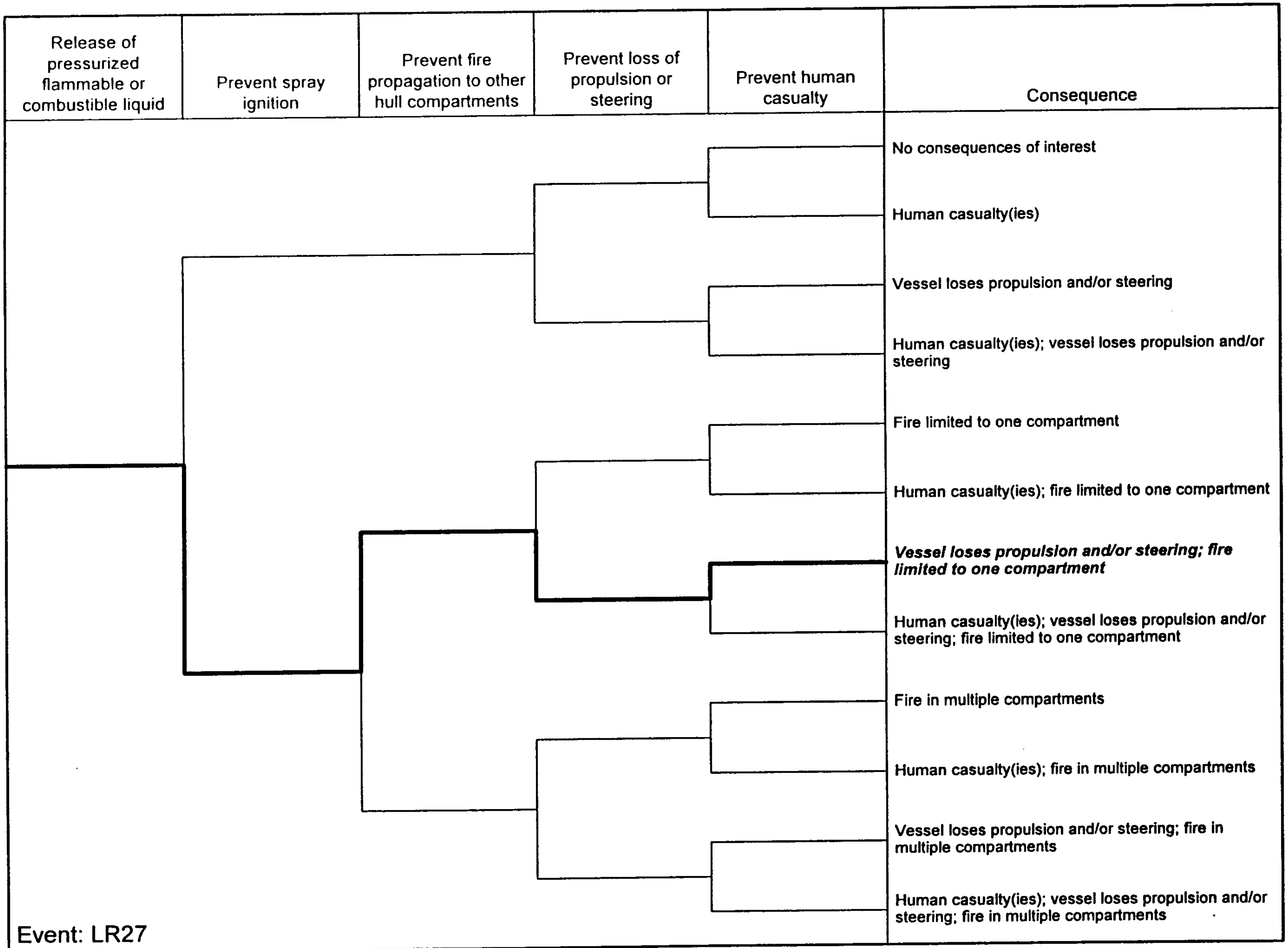
Revised 02/19/98 at 15:49

LR Number: 7385617 Degree of Severity: S
NOTE: This incident has the same LR number as the previous incident.

DAMAGED BY FIRE IN ENGINE ROOM AFTER FUEL INJECTION PUMP RUPTURED IN LAT. 05 12N., LONG. 12 56W., AT 1738 GMT ON 12/10/80. FIRE EXTINGUISHED AND TOWED TO DAKAR ROADS, THENCE TO ALGECIRAS FOR DISCHARGE. REPAIRED AND TRADING. ALL ELEC. APPARATUS & CONNECTIONS BURNT. ONLY SMALL GENS.WORKING FOR NAVIGAT. LIGHTS & COOKING. WATER IN ENGINE ABOVE GENS. DECK ROUND FUNNEL DAM. ACCOM. INTACT EXCEPT ELEC. PANELS & CABLES.

CAUSED BY RUPTURED FUEL INJECTION PUMP SPRAYING OIL WHICHWAS IGNITED BY UNKNOWN SOURCE.

Event Number: 7385617 (LR27)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Ruptured fuel injection pump, spraying oil that ignited by unknown source	
Ignition Source	Not known	Hot surface and/or autoignition
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated, but fire was extinguished	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		Loss of steering
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired. All electric apparatuses and connections were burnt, and only small generators were working (provided navigational lighting and cooking)	



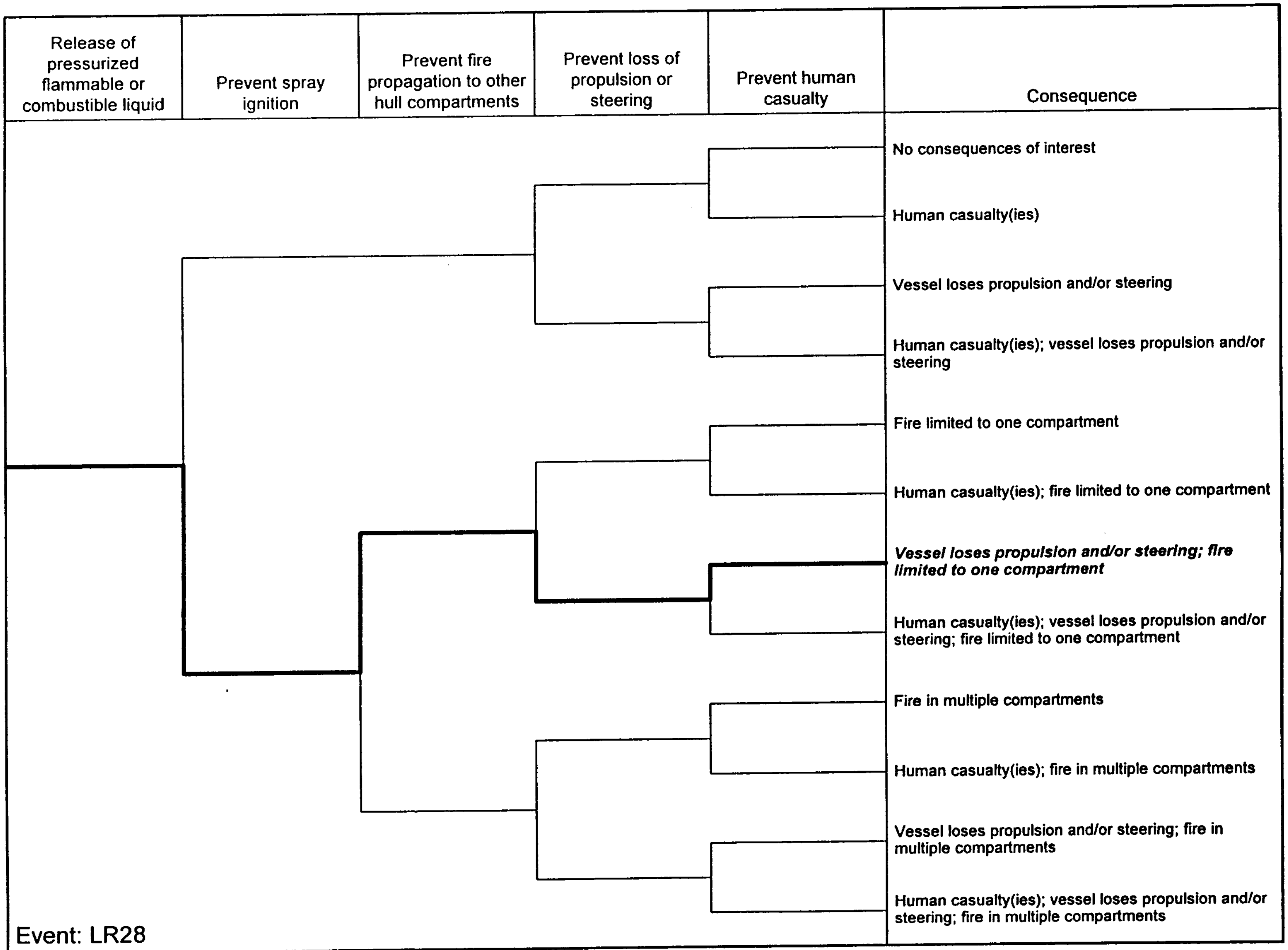
Revised 02/19/98 at 15:49

LR Number: 7390260 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM WHILST UPBOUND RIVER ST. CLAIRAT 2030 HRS ON 27/10/86. SUBSEQUENTLY TOWED TO STURGEON BAY WHERE ARRIVED 2/11/86 FOR REPAIRS.

FIRE EXTINGUISHED BY FIXED CARBON-DIOXIDE SYSTEM. CABLE TRUNK, AUXILIARY MOTORS AND WIRING DAMAGED.

Event Number: 7390260 (LR28)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Fixed CO_2 system	
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired, including cable trunk, auxiliary motor, and wiring	



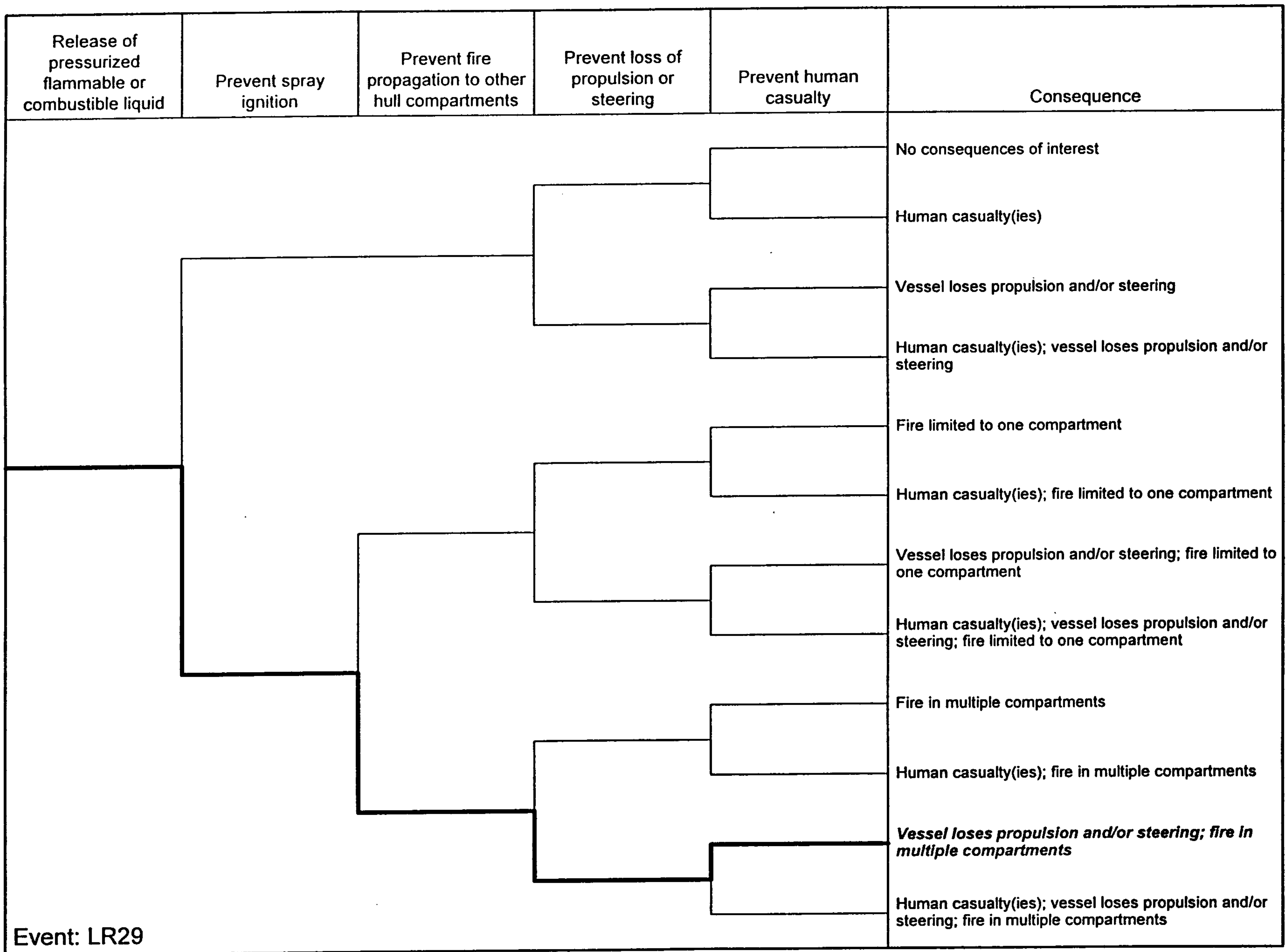
Revised 02/19/98 at 15:49

LR Number: 7396109 Degree of Severity: T

SUSTAINED CRACKED FUEL PIPE AND CONSEQUENT FIRE IN ENGINEROOM 290 MILES FROM ATTU ISLAND, BERING SEA, IN LAT. 56 58N., LONG. 179 58E., AT 2220HRS., ON 10/12/87; SUBSEQUENTLY SANK.

CREW SAFELY ABANDONED SHIP WHICH REPORTEDLY SANK

Event Number: 7396109 (LR29)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Cracked fuel pipe	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Unsuccessful (the vessel reportedly sank)	
Fire Suppression	Unsuccessful (the vessel reportedly sank)	
Impact on Propulsion		Loss of propulsion (the vessel reportedly sank)
Impact on Steering		Loss of steering (the vessel reportedly sank)
Human Casualty	No fatalities (crew safely abandoned ship)	
Corrective Action to Prevent Recurrence	No preventive action mentioned	

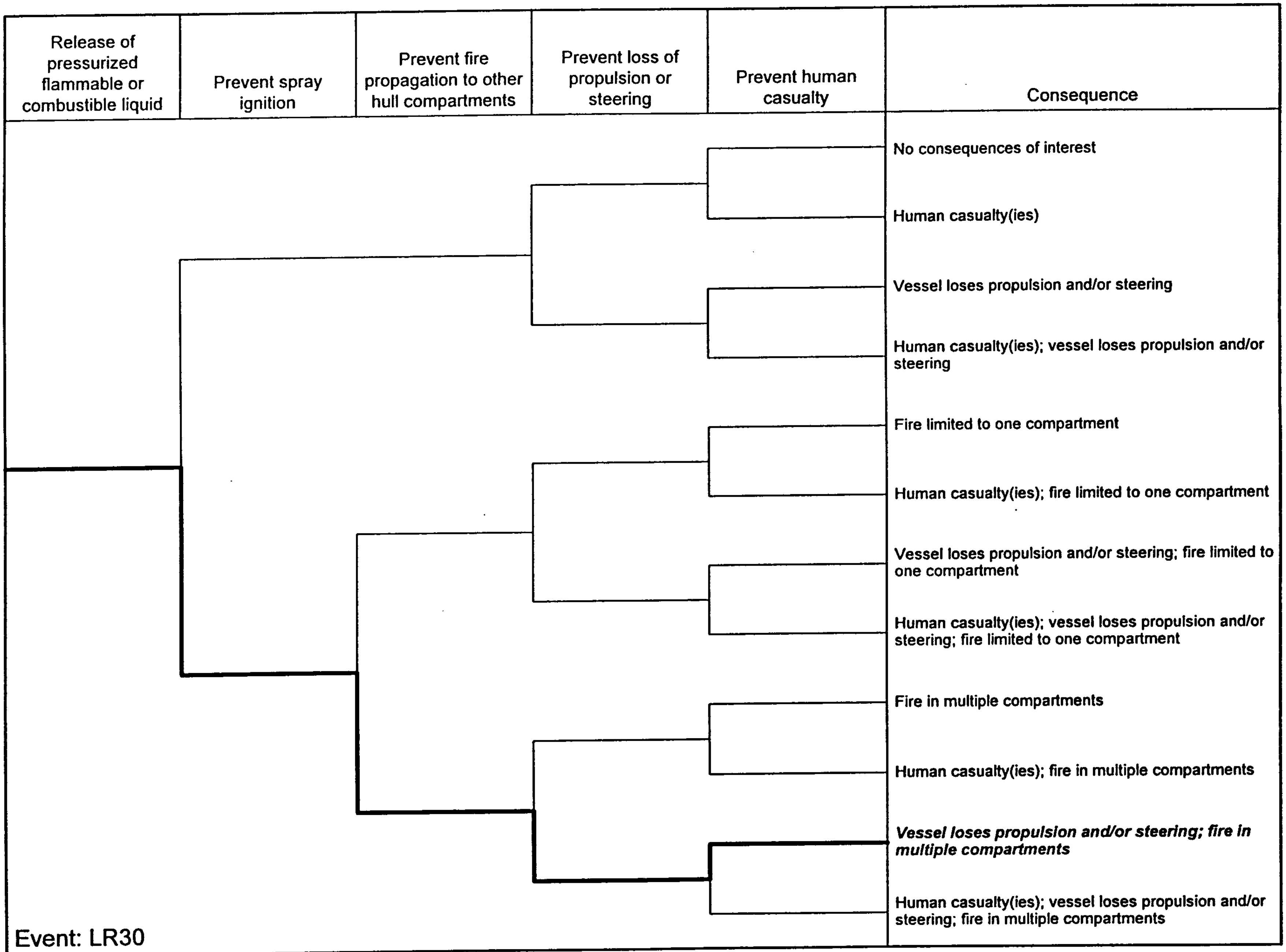


Revised 02/19/98 at 16:04

LR Number: 7410060 Degree of Severity: T

CAUGHT FIRE IN ENGINE ROOM AND SANK 68 MILES OFF AKAROA LIGHT, NEAR CHRISTCHURCH, NEW ZEALAND. IN APPROXIMATELY LAT. 44 08S., LONG. 174 37E., ON 28/5/79.

Event Number: 7410060 (LR30)	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	Not inferred
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion (the vessel sank)
Impact on Steering		Loss of steering (the vessel sank)
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned	

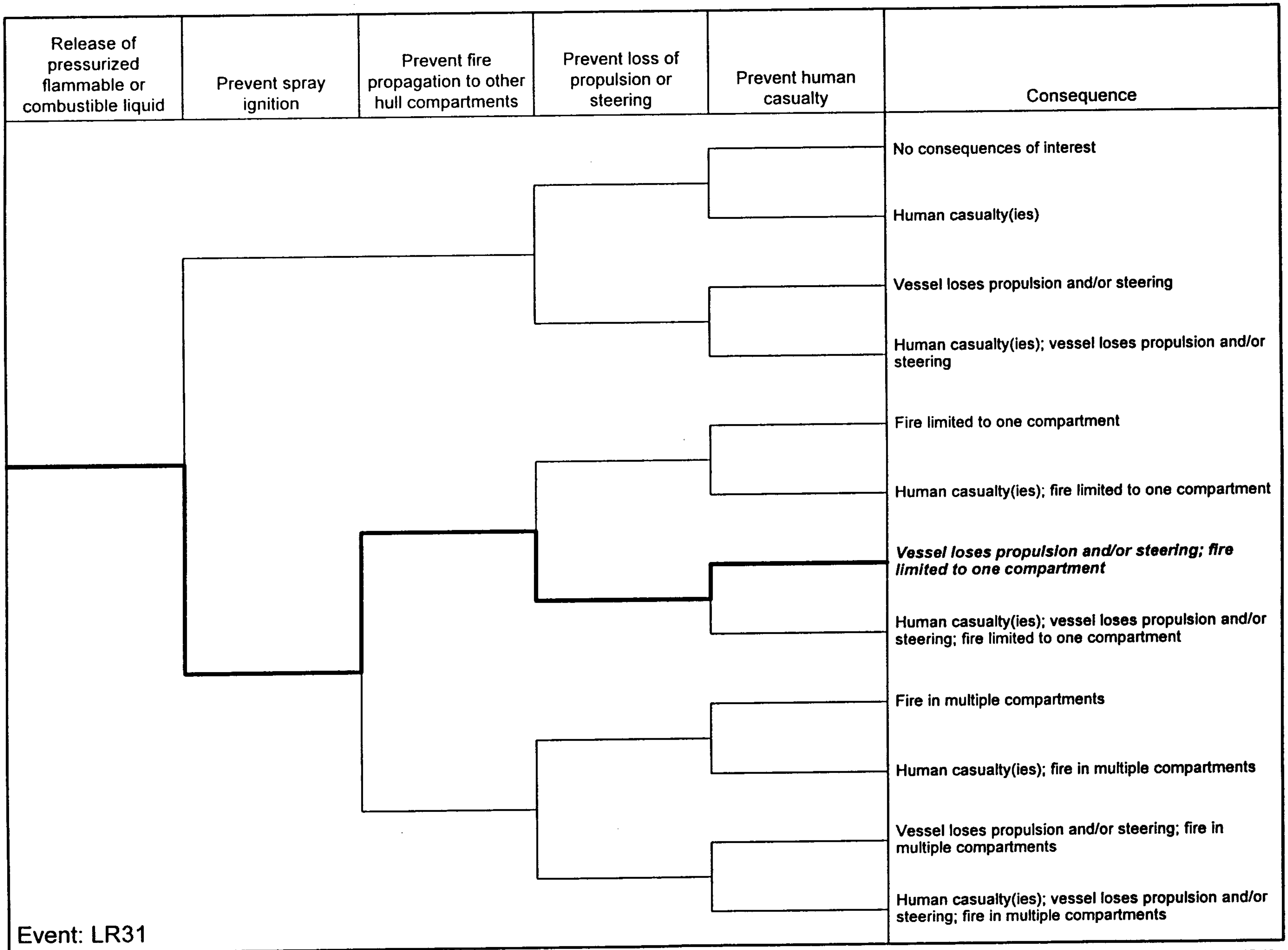


Revised 02/19/98 at 16:04

LR Number: 7423093 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM AND STRANDED IN ST. CLAIR RIVER ON 3/4/85. FIRE EXTINGUISHED. SUBSEQUENTLY REFLOATED AND TOWED TO SARNIA, ONT. REPAIRED.

Event Number: 7423093 (LR31)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Not stated/engine room	
Cause	Not stated	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated, but the fire was extinguished	Not inferred
Impact on Propulsion		Loss of propulsion (vessel had to be towed)
Impact on Steering		Loss of steering
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



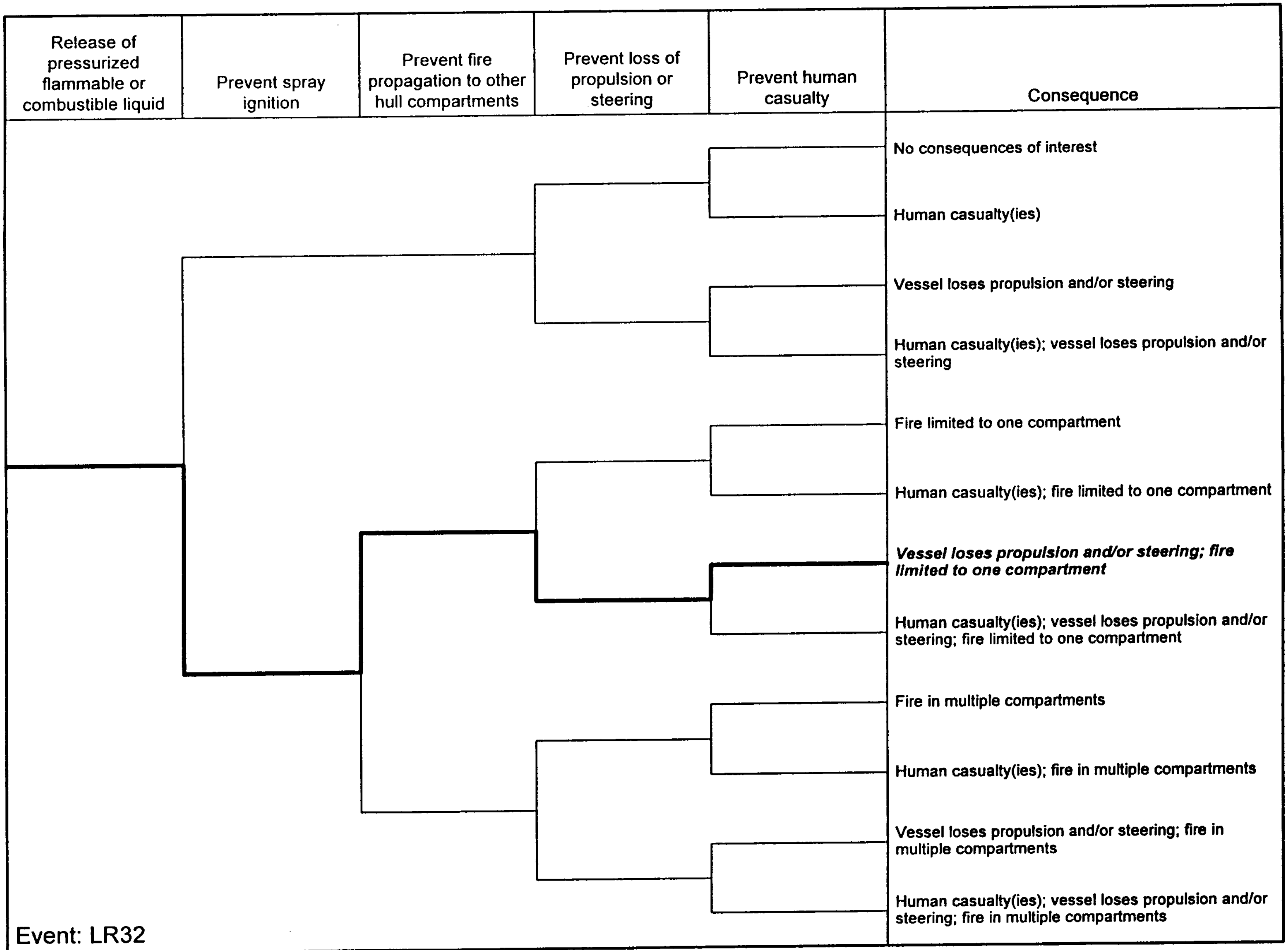
Revised 02/19/98 at 15:49

LR Number: 7503843 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM DUE TO LUB OIL PIPE RUPTURING, SPRAYING OIL OVER ENGINE WHILST ON VOYAGE FROM INDIA TO PORT KEMBLA ON 9/11/85. ARRIVED AT PORT KEMBLA 20/11/85, TEMP REPS EFFECTED AND SAILED SAME DAY, RESUMING SERVICE.

LUB OIL PIPE TO EXHAUST GAS DRIVEN TURBO BLOWER OF CENTRE GENERATOR ENGINE RUPTURED, SPRAYING OIL OVER CENTRE AND STARBOARD GENERATOR ENGINE. EXTENSIVE DAMAGE TO POWER CABLES AND EXTENSIVE DAMAGE TO INSTRUMENTATION ON GENERATOR ENGINES.

Event Number: 7503843 (LR32)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Lube oil pipe to exhaust gas-driven turbo blower for the center generator engine ruptured	
Ignition Source	Hot surface (center and starboard generator engines)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Temporary loss of propulsion (temporary repairs allowed the vessel to sail on the same day)
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired. There was extensive damage to power cables and instrumentation on the generator engines	



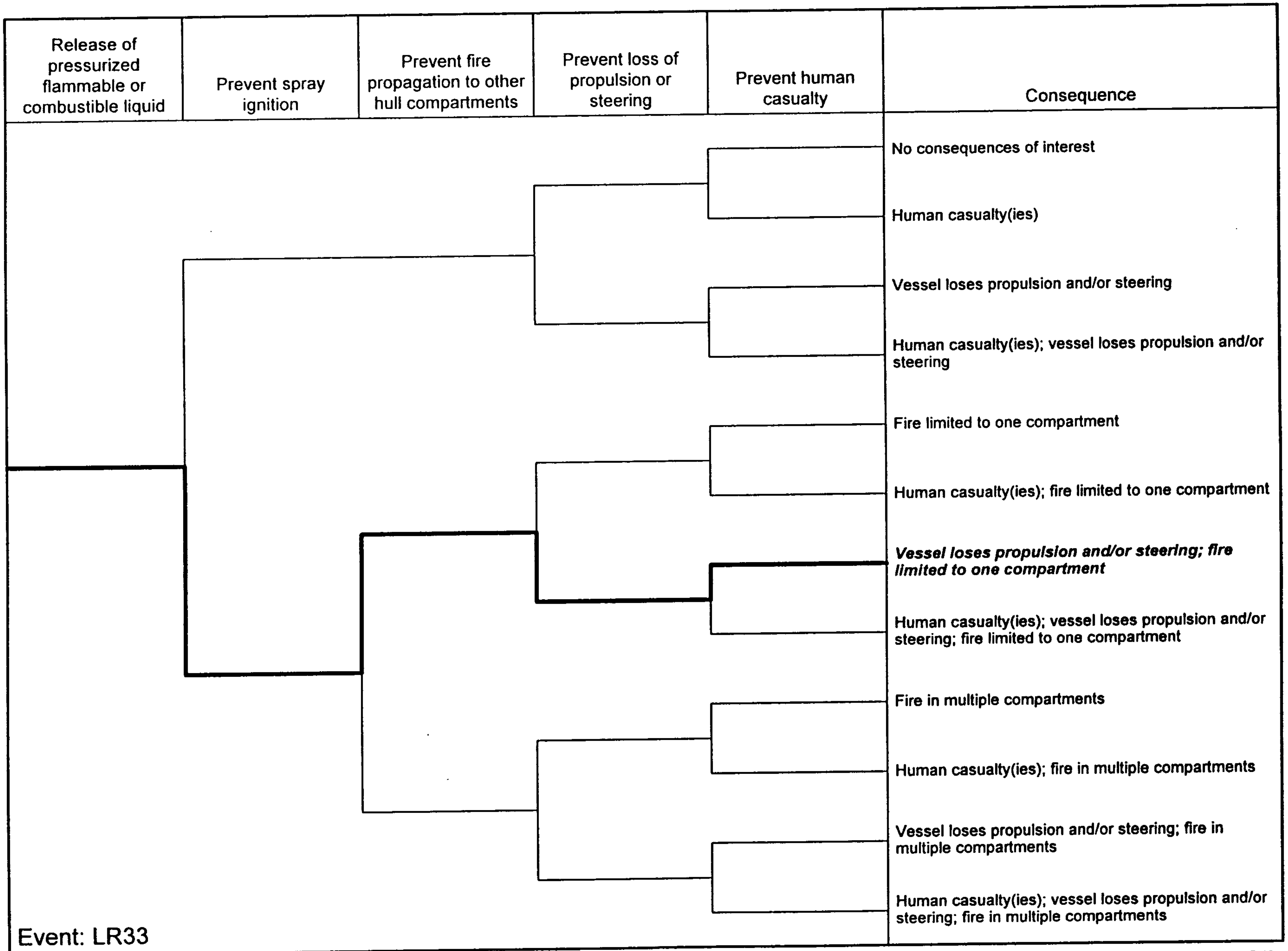
Revised 02/19/98 at 15:49

LR Number: 7506027 Degree of Severity: N

CAUGHT FIRE IN ENGINE ROOM OFF ULSAN ON 4/12/96 AFTER LUBRICATING OIL LEAK. FIRE BROUGHT UNDER CONTROL BY CREW. ARRIVED PORT ANGELES, WA., ON 19/12/96.

SOURCE OF THE FIRE WAS THE MAIN ENGINE GLAND SEAL REGULATOR WHICH APPARENTLY DEVELOPED A LUBRICATING OIL LEAK. THE OIL RAN UNDER THE LAGGING ON TO A COUPLE OF LINES. WHEN ENGINES WERE BROUGHT UP TO SEA SPEED, ONE LINE HEATED UP AND THE LAGGING FLASHED.

Event Number: 7506027 (LR33)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	The main engine gland seal regulator developed a lube oil leak. The oil ran under the lagging on to a couple of lines. When the engines were brought up to sea speed, one line heated up and the lagging flashed	
Ignition Source		Hot surface (steam line)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Crew	
Impact on Propulsion		Temporary loss of propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred

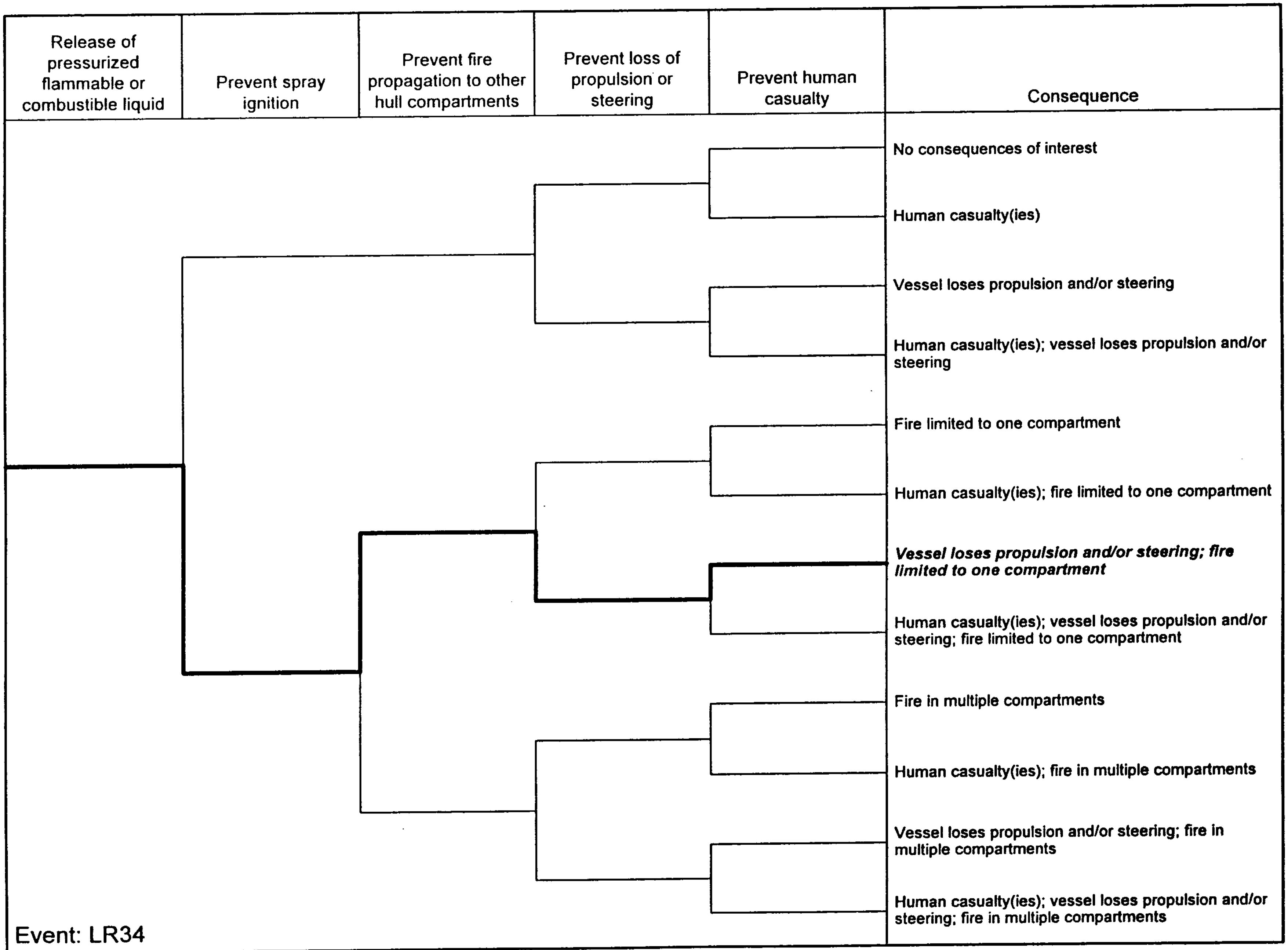


Revised 02/19/98 at 15:49

LR Number: 7700386 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM DUE TO FUEL OIL PIPELINE SPRINGING A LEAK IN LAT. 08 45N. LONG. 69 20E. ON 16/12/79. SUBSEQUENTLY PROCEEDED TO BAHRAIN WHERE REPAIRS EFFECTED & VESSEL RETURNED TO SERVICE.

Event Number: 7700386 (LR34)	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Fuel oil/engine room	
Cause	Fuel oil line leak	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Temporary loss of propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



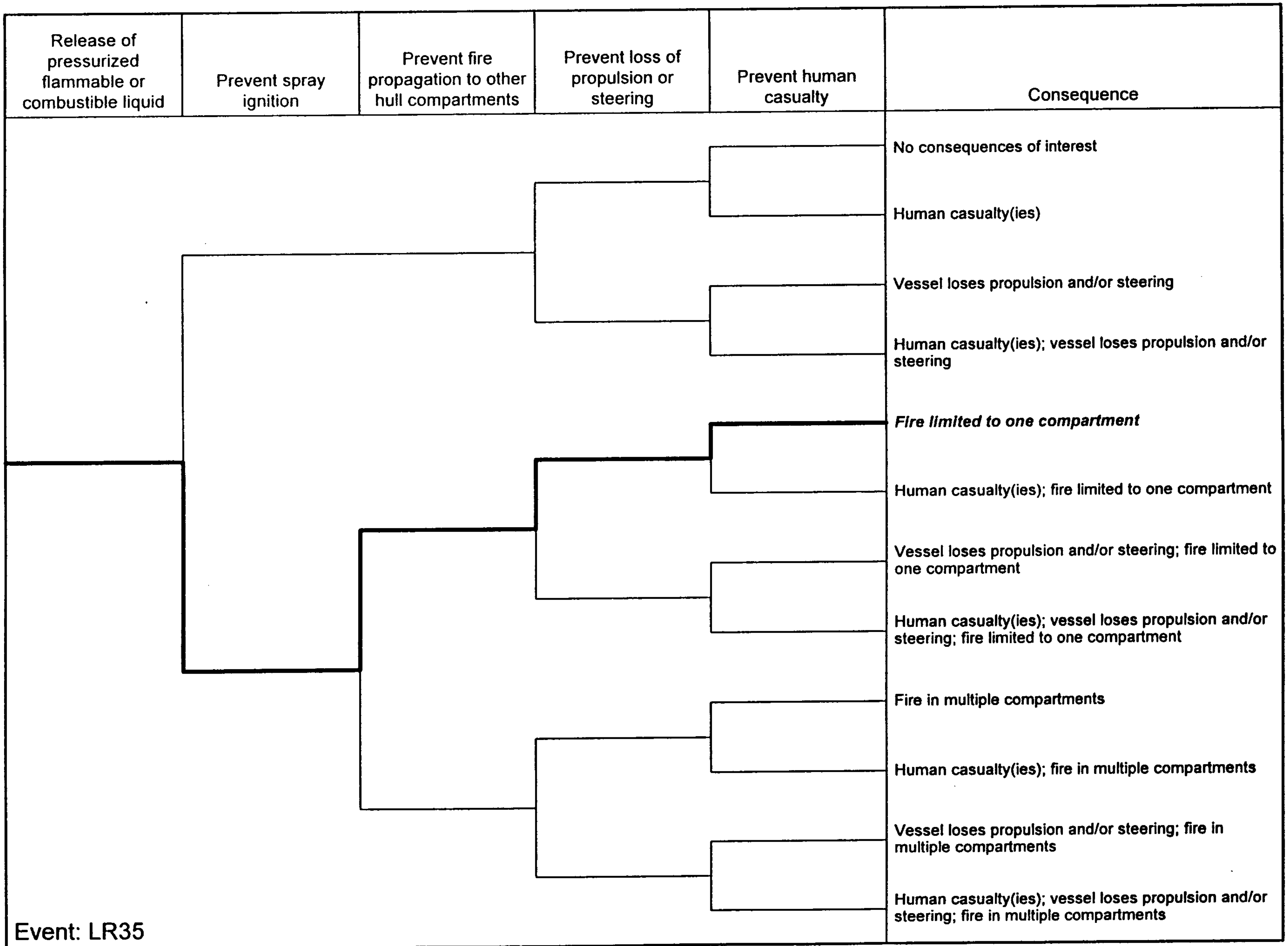
Revised 02/19/98 at 15:49

LR Number: 7708833 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM IN LAT. 45 38N., LONG. 13 25W., ON 25/10/84 AND DIVERTED TO FALMOUTH, WHERE ARRIVED 29/10/84. REPAIRS EFFECTED AND SAILED 11/11/84 FOR LOS ANGELES. DETAILS OF DAMAGE NOT REPORTED.

REPORTED FIRE DUE TO FUEL PUMP LEAK.

Event Number: 7708833 (LR35)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Fuel pump leaked	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		None
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired, but details of the damage were not provided	



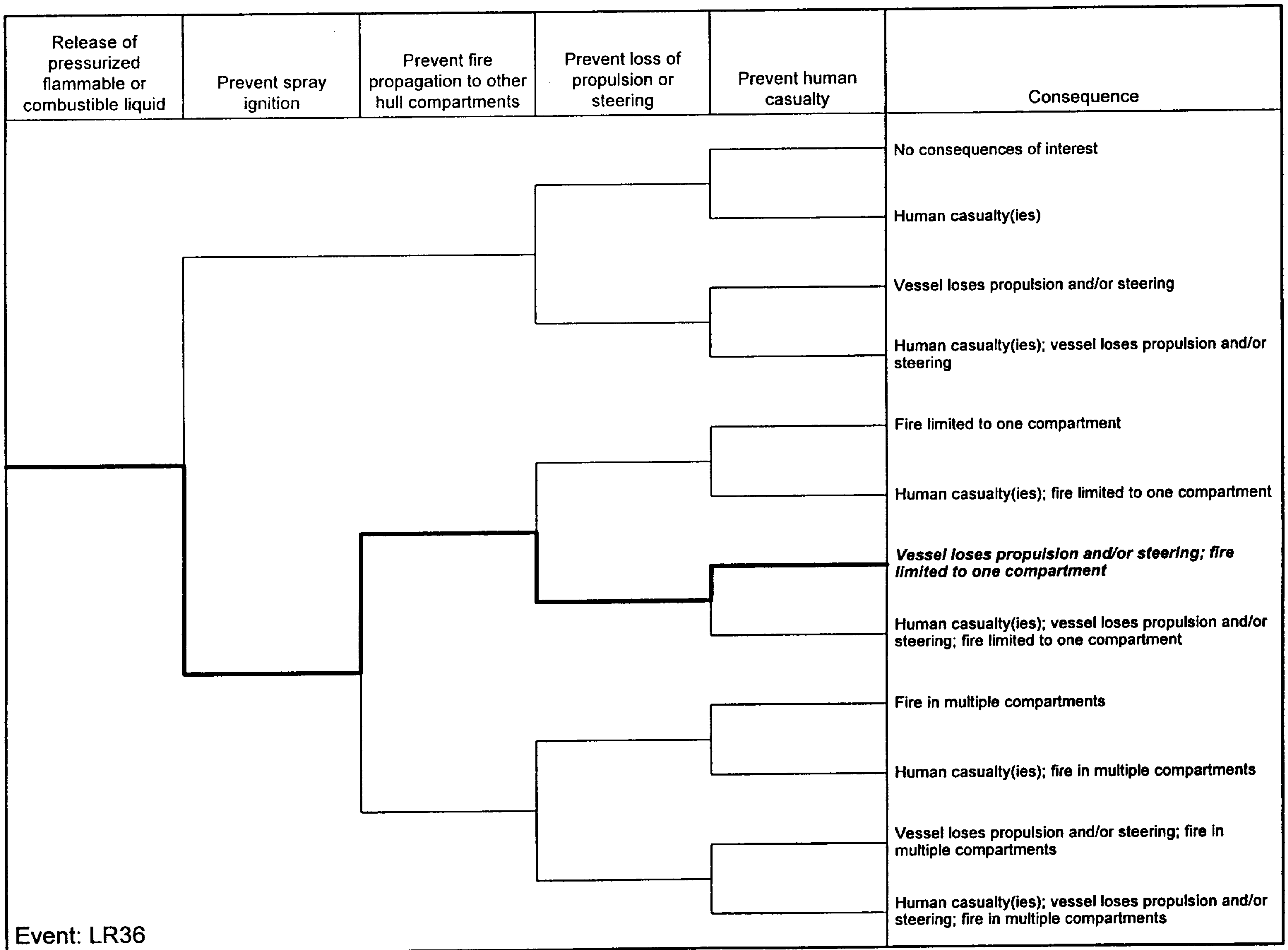
Revised 02/19/98 at 15:49

LR Number: 7800241 Degree of Severity: S

ENGINE ROOM FIRE IN LAT. 28 04N., LONG. 43 49W., ON 9/4/79|TOW & BERTHED AT BREST WHERE REPAIRED.

FIRE DUE TO LUB. OIL PUMPS. REP(D). MAIN PROPULSION PLANT PRIOR TO GETTING UNDERWAY. SURVEYED AT TUXPAN WHERE EXTENSIVE REPAIRS CARRIED OUT UNDER BUILDERS SUPERVISION & EXPECTED COMPLETION IN MAY.

Event Number: 7800241 (LR36)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Fire due to lube oil pumps (no details provided)	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was extensively repaired	



Revised 02/19/98 at 15:49

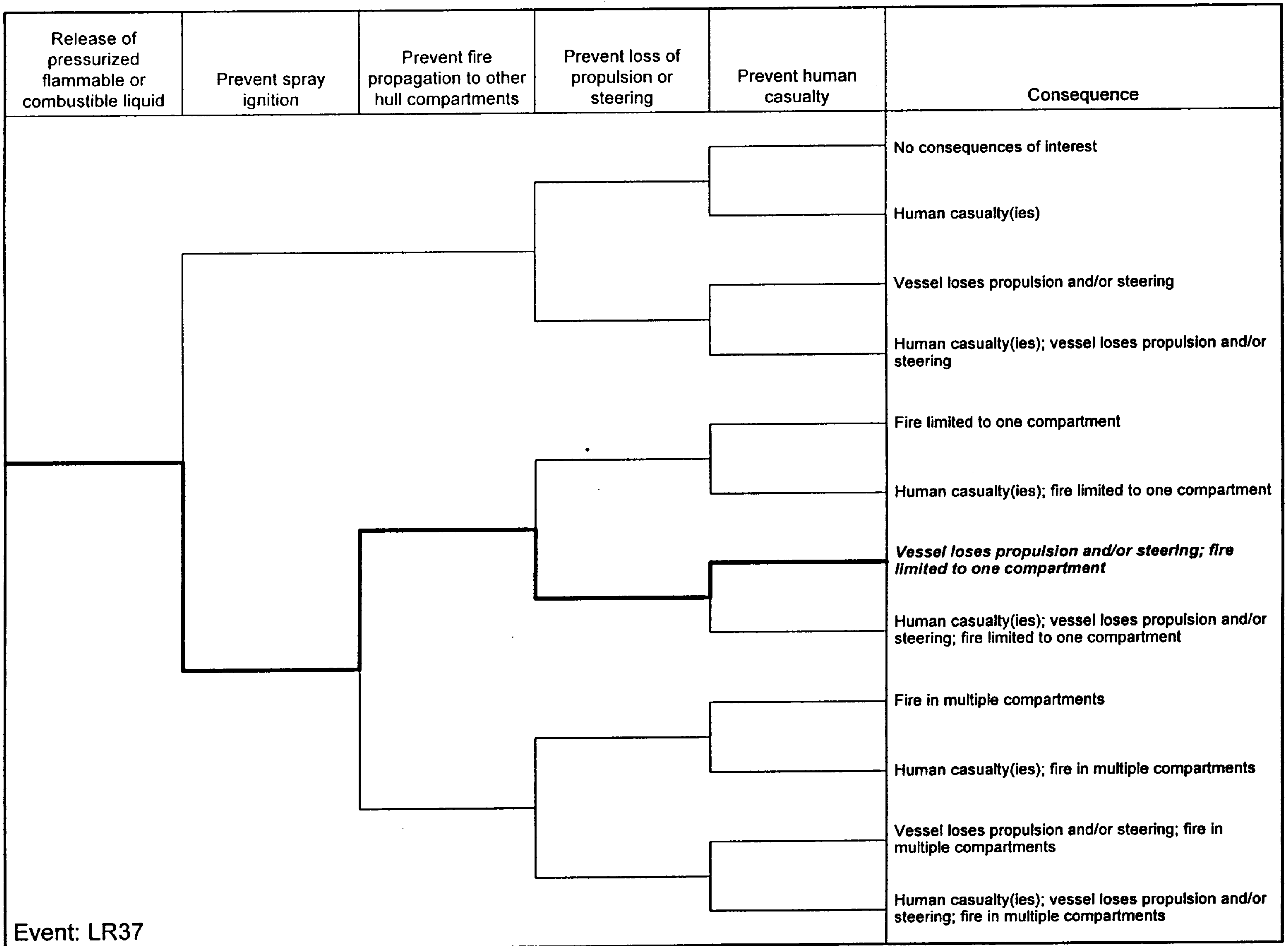
LR Number: 7826192 Degree of Severity: N

DAMAGED BY FIRE IN ENGINE ROOM AT SINGAPORE ROADS ON 26/7/86. FIRE EXTINGUISHED BY CREW. REPAIRS EFFECTED DURING VESSEL'S DISCHARGE AT SINGAPORE. SAILED 12/9/86 FOR INDONESIA.

HIGH PRESSURE MAIN ENGINE FUEL PIPE FRACTURED, SPRAYING OIL ONTO HOT EXHAUST MANIFOLD. FIRE WAS EXTINGUISHED BY USING FITTED FOAM-SMOTHERING SYSTEM.

DAMAGE CONSISTS OF INSTRUMENTATION CABLES, INSULATION AND TURBO-BLOWER FILTERS AT FORWARD END OF ENGINE. DRYDOCKING NOT REQUIRED.

Event Number: 7826192 (LR37)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	A high pressure fuel pipe for the main engine fractured	
Ignition Source	Hot surface (exhaust manifold)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Crew used fixed foam-smothering system	
Impact on Propulsion		Loss of propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired. Damage consisted of instrumentation cables, insulation, and turbo-blower filters at forward end of engine. Dry docking was not required	



Revised 02/19/98 at 15:49

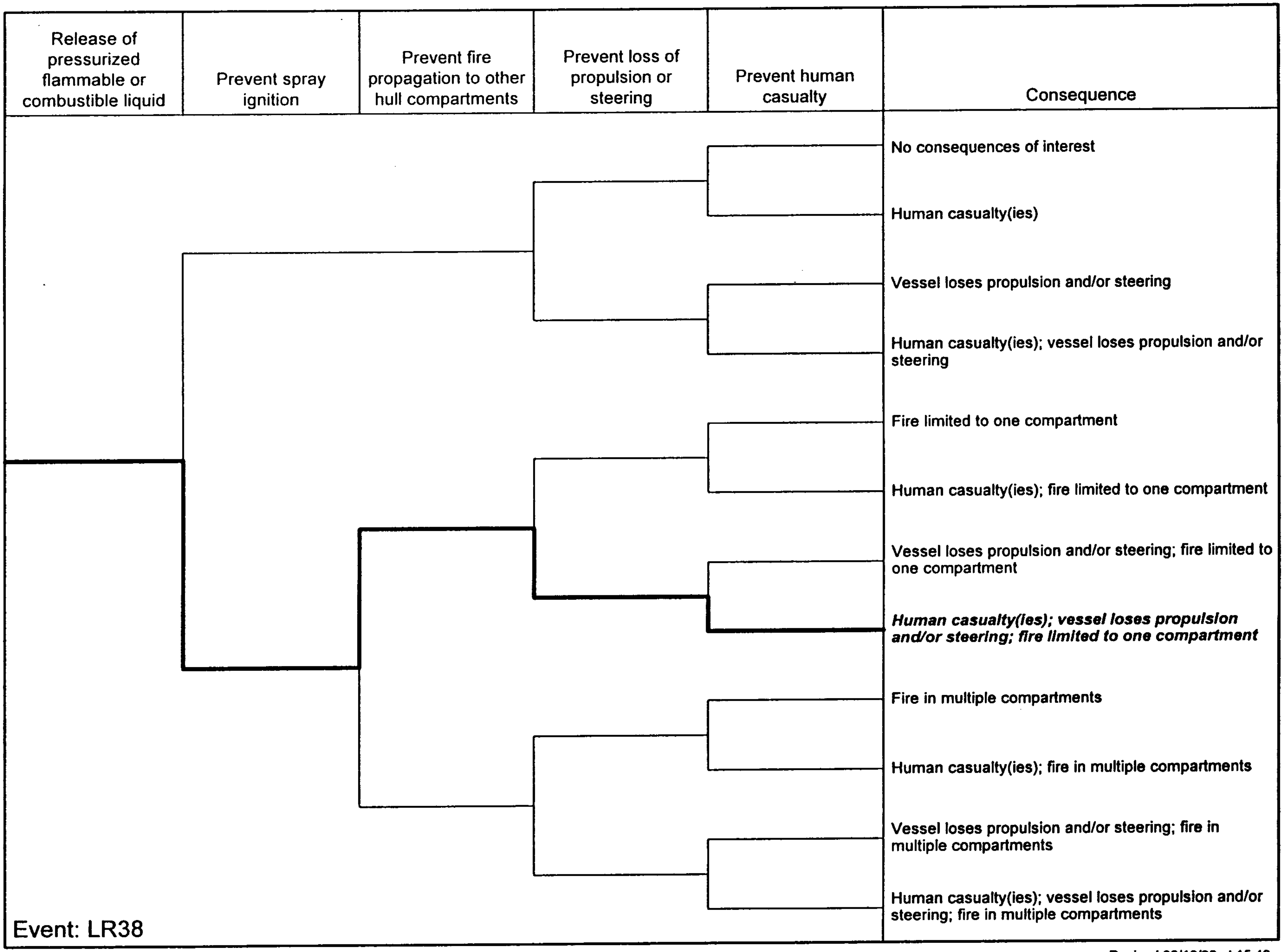
LR Number: 7826867 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM 25 MILES E. OF RAMSGATE, IN LAT. 51 15N., LONG. 02 09E., ON 23/5/88. FIRE EXTINGUISHED WITH ASSISTANCE. VESSEL TOWED TO DUNKIRK; SUBSEQUENTLY TAKEN TO BREMERHAVEN. REPAIRED. RETURNED TO SERVICE.

REPORTED FIRE CAUSED BY FRACTURED FUEL PIPE.

1 CREW MEMBER DEAD.

Event Number: 7826867 (LR38)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	A fuel pipe fractured	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	One fatality	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



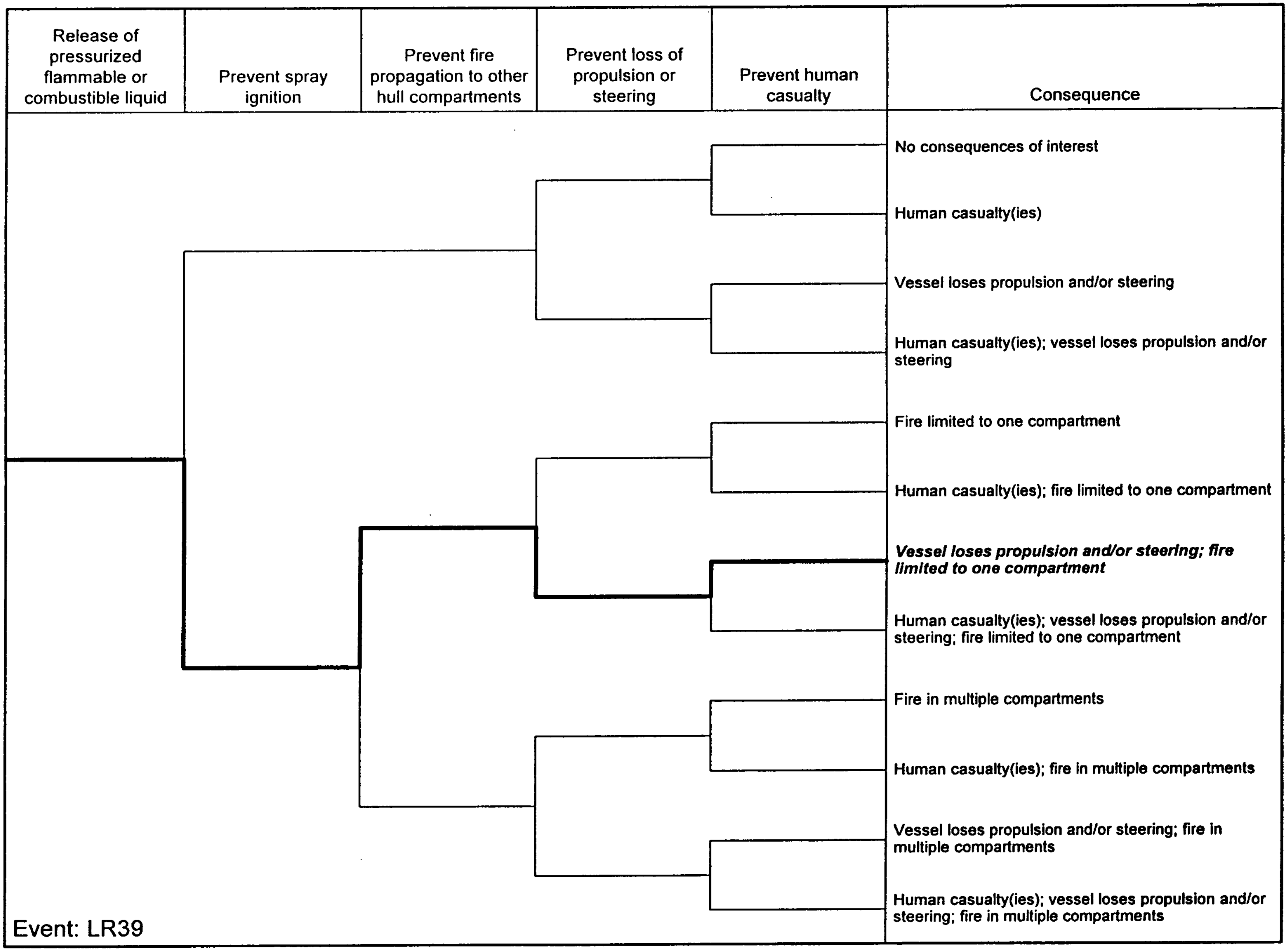
Revised 02/19/98 at 15:49

LR Number: 7908536 Degree of Severity: S

CAUGHT FIRE IN ENGINE ROOM IN LAT.43 17N., LONG.40 06W., ON 23/6/81. FIRE EXTINGUISHED IN 1 HR. TOWED TO ANTWERP WHERE PART PERMANENT REPAIRS EFFECTED. RESUMED TRADING; SUBSEQUENTLY ARRIVED INNOSHIMA 2/2/82 & COMPLETED REPAIRS.

FIRE DUE TO PULSAT OR DAMPER BREAKING AND SPRAYING HOT FUEL OIL ON TO ENGINE. SUSTAINED DAMAGE TO ELECTRICAL EQUIPMENT MAIN ENGINE CONTROLS AND CRANKCASE. PART PERM REPS TO ELEC EQUIP. AND M.E. CONTROLS AND TEMP REPS TO M.E. CRANKCASE. SUCCESSFUL ENGINE TRIALS COMPLETED. OWS INTEND TO CARRY 2ADD. CREW MEMBERS FOR CLEANING AND PAINTING OF E.R. STRAIN GUAGE READINGS TAKEN DURING ENGINE TRIALS IN WAY OF META-LOCK REPAIR TO M.E. ENTABLATURE AND FOUND SATISFAC.

Event Number: 7908536 (LR39)	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Fuel oil/engine room	
Cause	A pulsating damper broke, spraying hot fuel oil onto the engine	
Ignition Source	Hot surface (exhaust manifold or exhaust pipe)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



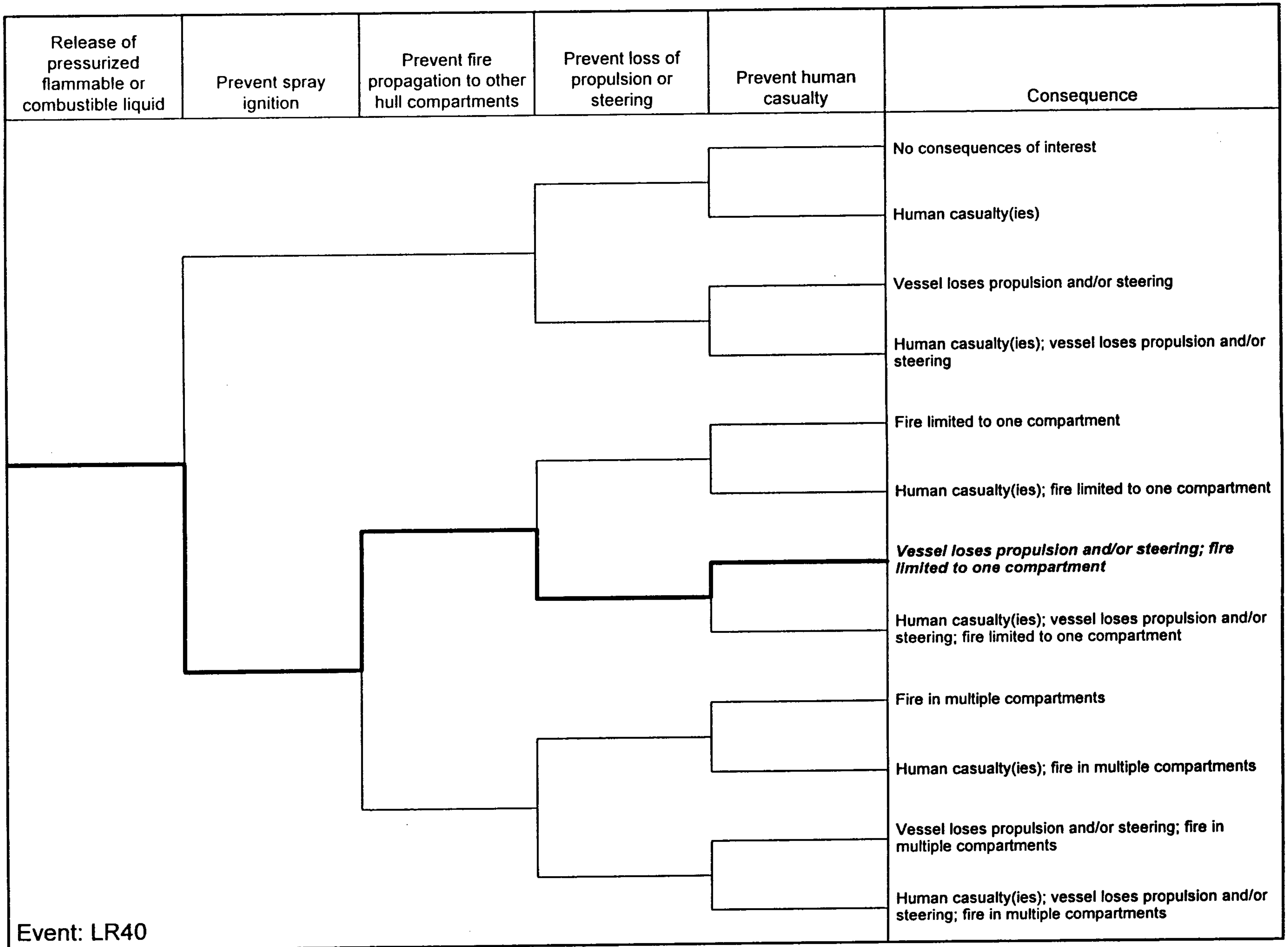
Revised 02/19/98 at 15:49

LR Number: 7911703 Degree of Severity: S

CAUGHT FIRE IN ELECTRICAL EQUIPMENT IN ENGINE ROOM 90 MLS. N. OF ALEXANDRIA ON 7/11/83, TOWED TO ALEXANDRIA AND THEN AND BERTHED 1700 SAME DAY FOR SURVEY AND LATER ARRIVED BARCELONA 28/11/83 IN TOW FOR REPAIRS. VARIOUS ELECTRIC POWER AND AUTOMATION CABLES AND WIRES IN ENGINE-ROOM BURNT. ELECTRICAL AND OTHER AUXILIARY EQUIPMENT SOOT AND SMOKE BLACKENED. ACCOMMODATION GENERALLY IN MINOR INTERNAL SMOKE BLACKENED.

SEVERE LOSS OF MAIN ENGINE LUBRICATING OIL TO ENGINE ROOM THROUGH A LUBRICATING OIL FILTER COVER.

Event Number: 7911703 (LR40)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Severe loss of main engine lubricating oil to engine room through a lubricating oil filter cover	
Ignition Source	Not stated	Not inferred
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Loss of propulsion (the vessel had to be towed)	
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired. Damage included various electric power and automation cables/wires. Electrical and other auxiliary equipment were blackened by soot and smoke	

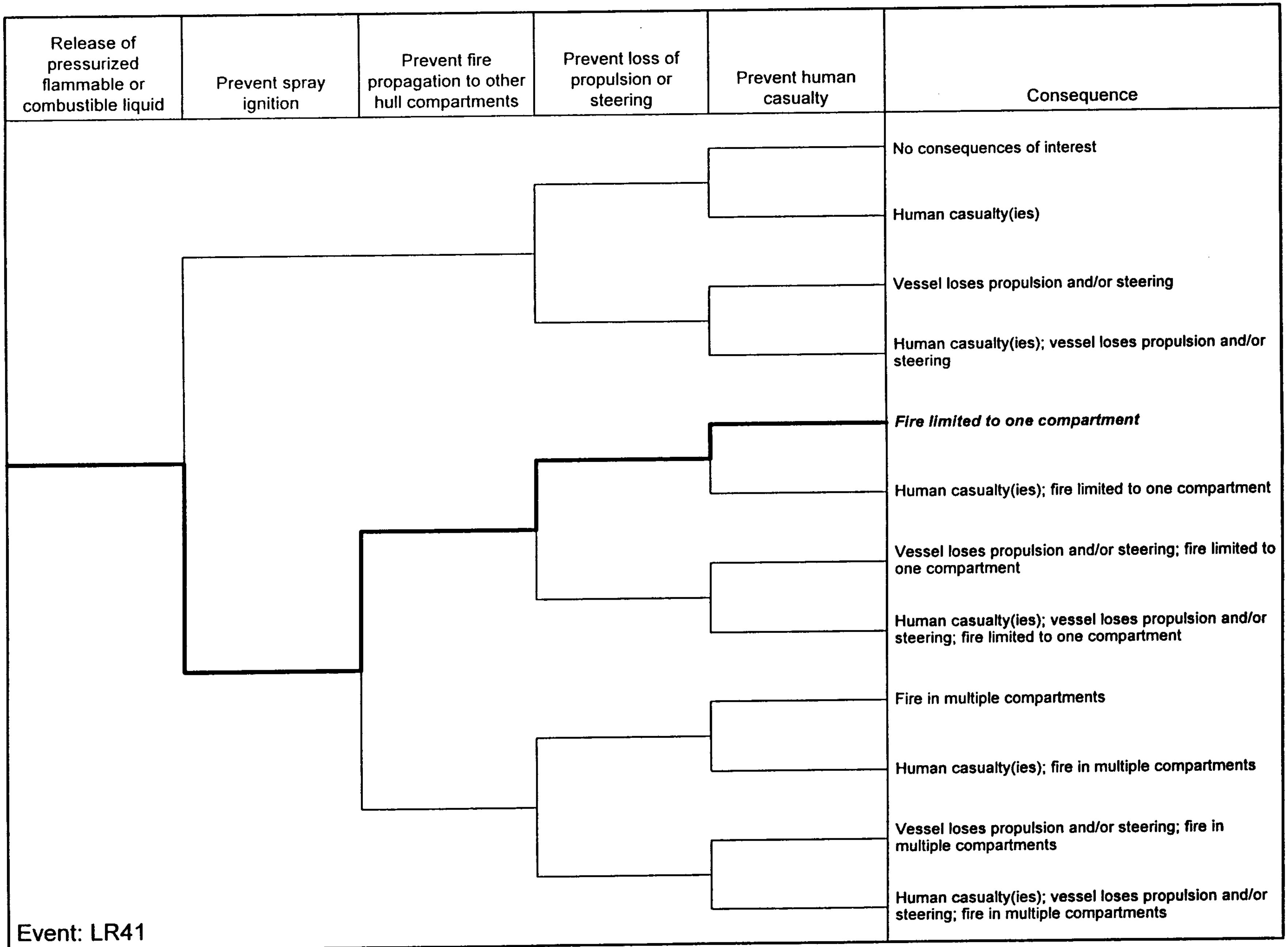


Revised 02/19/98 at 15:49

LR Number: 7926540 Degree of Severity: N

CAUGHT FIRE IN STARBOARD ENGINE ROOM IN LAT. 33 04N., LONG. 70 55W., ON 7/6/84. FIRE EXTINGUISHED USING CARBON DIOXIDE. PROCEEDED JACKSONVILLE ON PORT ENGINE FOR SURVEY. PERMANENT REPAIRS EFFECTED. OWNERS ALLEGE FIRE DUE TO FAILURE OF AN ELBOW IN MAIN ENGINE FUEL SUPPLY LINE WHICH ALLOWED FUEL TO SPRAY ONTO ENGINE EXHAUST. CAUSE OF FAILURE REMAINS UNDER INVESTIGATION. RENEWAL OF APPROX. 90,000 FT OF POWER AND LIGHTING CABLE WITH CABLE TRAYS, LIGHT FIXTURES AND DISTRIBUTION PANELS, 56 ELECTRIC MOTORS OVERHAUL, 6 MOTORS REWIND, 2 MOTORS RENEW, 1 ALTERNATOR REWIND, 5 MOTOR STARTER BOXES RENEW, INSULATION RENEW ETC.

Event Number: 7926540 (LR41)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	Failure of an elbow in the main engine fuel supply line, which allowed fuel to spray onto an engine exhaust	
Ignition Source	Hot surface (exhaust pipe)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	CO_2	
Impact on Propulsion		Partial loss of propulsion (the vessel proceeded on port engine)
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired. Damage included 90,000 ft of power and lighting cable, light fixtures, distribution panels, 64 electric motors (56 overhauled, 6 rewound, and 2 renewed), alternator (rewound), 5 motor starter boxes (renewed), insulation, and so forth	



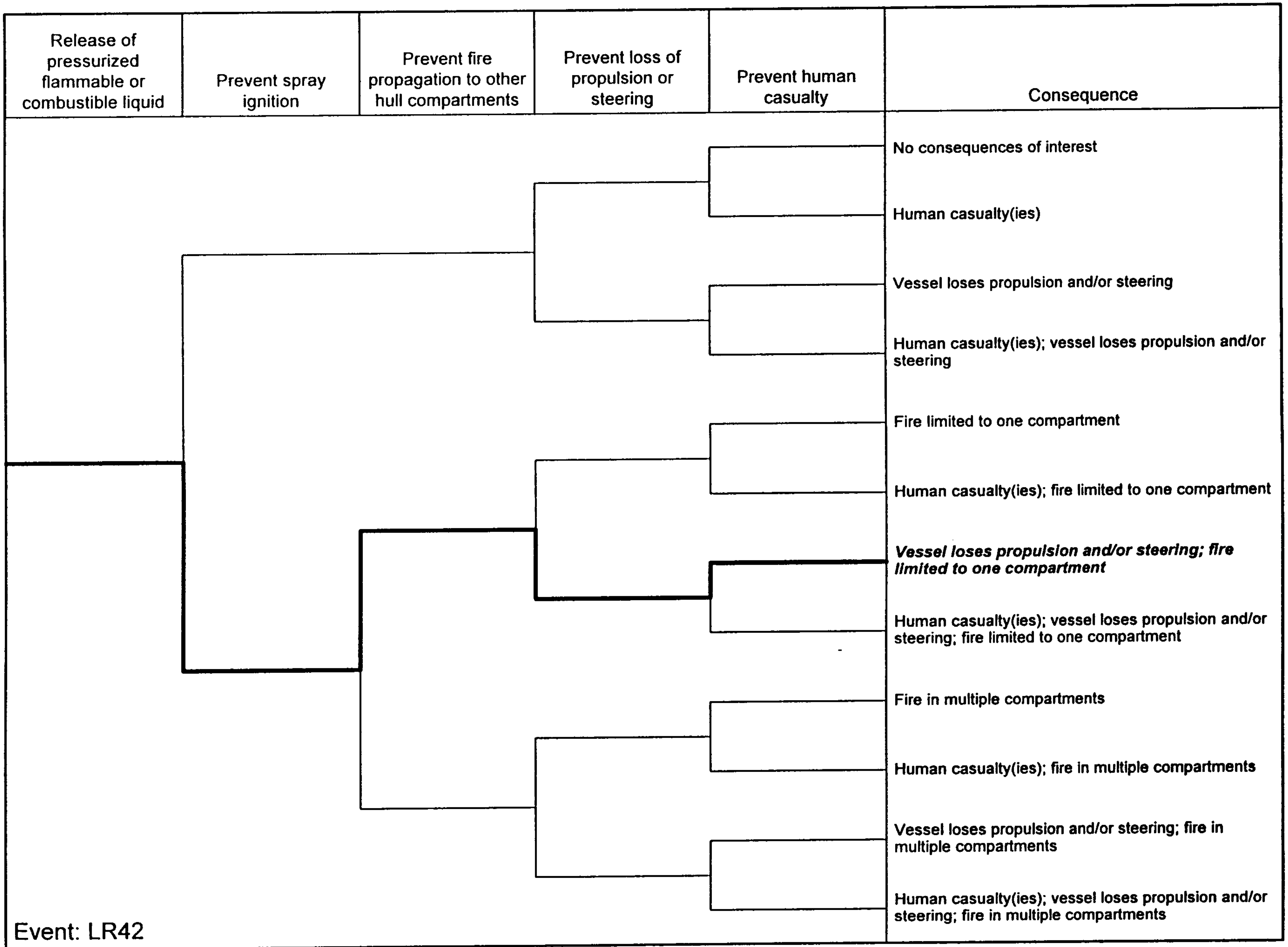
Revised 02/19/98 at 15:49

LR Number: 8881369 Degree of Severity: N

CAUGHT FIRE IN ENGINE ROOM WHILE IN BLACK SEA ON 2/3/97. FIRE EXTINGUISHED SAME DAY. ANCHORED OFF AHIRKAPI 5/3/97. REPAIRS COMPLETED 8/4/97.

FUEL PIPE OF THE NO. 2 CYLINDER OF THE STARBOARD ENGINE BURST IN ENGINE ROOM.

Event Number: 8881369 (LR42)	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	The fuel pipe of the No. 2 cylinder of the starboard engine burst in the engine room	
Ignition Source		Hot surface (exhaust manifold or exhaust pipe)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Loss of propulsion
Impact on Steering		None
Human Casualty	No fatalities	
Corrective Action to Prevent Recurrence	No preventive action mentioned – the vessel was repaired	



Revised 02/19/98 at 15:49

APPENDIX D

Nippon Kaiji Kyokai (NK) Event Characterization Tables

This attachment presents the analysis of selected events documented in *Engine Room Fire – Guidance to Fire Prevention* (the "NK Report"), published by the Japanese classification society Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994. In response to a large number of engine room fires in the 1980s and early 1990s, NK established a study committee on the prevention of engine room fires. The committee investigated actual conditions and causes of more than 70 engine room fires in NK-classed ships during 13 years from 1980 through 1992. (This is almost 6 ships per year, which is 0.1% of all the 6,000 vessels classed by NK.) Of these fires, a total of 39 (about half) involved fuel or lube oil systems in the engine room.[1] The results and recommendations from the committee are documented in the NK Report.

The NK Report does not include a description of most events, but it does provide the cause of each fire. The NK Report also provides several summary statistics (e.g., means of fire detection and suppression) of interest even though this information is not documented for individual events.

This attachment presents the event description (when available) and the event characterization table for each of the 39 events in the NK Report that involved fuel or lube oil systems in the engine room. The event descriptions are taken directly from the NK Report (we have not edited or modified these descriptions). The event characterization table provides comments (as documented in or as inferred from the NK Report) about the system/location and cause. For individual events, not much detail is provided about the ignition source, means of detection, means of release isolation, means of fire suppression, impact on propulsion, impact on steering, human casualty, and corrective action. Thus, the event characterization tables for the NK events contain less information regarding these items than the tables for the events presented in Attachments A, B, C, E, F, and G.

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[1] There is some discrepancy in the number of events considered in the NK report. Page 14 indicates a total of 38 events involving fuel oil or lube oil systems in the engine room, including *2* events involving the short sounding pipe for the fuel oil (FO) tank. Page 15 indicates only *one* involving the short sounding pipe for the FO tank. Page 57 provides detailed descriptions of *three* events involving the short sounding pipe for the FO tank.

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Event Description: Not available.

Event Number: NK01	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Disconnection of a drain valve in the fuel oil supply piping from the main engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

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Event Description: Not available.

Event Number: NK02	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of an air relief valve in the fuel oil supply piping from the main engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

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Event Description: Not available.

Event Number: NK03	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of cock in the fuel oil return piping from the main engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

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Event Description: FO leaked onto the M/E exhaust gas pipe and fire broke out because the vinyl hose, which was temporarily fitted to the bottom cover of the FO mixing column, was disconnected. (Description extracted from Photo 4, page 29, of the NK Report – also see Figure 11, page 28).

Event Number: NK04	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Disconnection of a vinyl hose in the fuel oil return piping for the main engine	
Ignition Source	Hot surface (exhaust gas pipe)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	One fatality	
Corrective Action to Prevent Recurrence[a]	Provide means to ensure that non-approved parts (e.g., pipe, gasket) will not be used in fuel oil and lube oil systems Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

[a] NK Report, pages 15, 16, 28, 29, 41, and 42.

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Event Description: FO sprayed out through a crack situated close to the connecting flange between the FO supply pipe and the FO injection pump of the Main Engine, and resulted in No. 2 Generator catching fire. (Description extracted from Figure 5, page 24, of the NK Report).

Event Number:	Event Characterization	
NK05	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Crack in a welding seam in a fuel oil pipe connection for the main engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 24, 41, and 42.

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Event Description: FO sprayed out from the flange between the No. 4 cyl. FO supply pipe and the FO injection pump because two fitting bolts became loose and disconnected. Leaked FO touched a 400 Celsius hot-point on the exhaust gas manifold, resulting in fire. (Description extracted from Figure 13, page 32, of the NK Report).

Event Number: NK06	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of two fitting bolts between the fuel oil inlet pipe and the fuel oil injection pump for the main engine	
Ignition Source	Hot surface (exhaust gas manifold)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 27, 32, 41, and 42.

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Event Description: Not available.

Event Number: NK07	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of one fitting bolt between the fuel oil inlet pipe and the fuel oil injection pump for the main engine	
Ignition Source		Hot surface (exhaust gas manifold — see NK06)
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 27, 41, and 42.

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Event Description: FO sprayed out due to the connection between the sheath heater and the electric cable box of the FO heater becoming loose and resulting in fire. (Description extracted from Figures 6, 7, 8, and 9, page 26, of the NK Report).

Event Number: NK08	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	An incorrect fitting caused a leak from the fuel oil electric sheath heater for the main engine. (The fitting type was gland nut with asbestos packing)	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The manufacturer changed the design of the fitting between the sheath heater and the cable box from using a gland nut to a welded connection	

[a] NK Report, pages 15, 16, and 26.

[Blank]

Event Description: Not available.

Event Number: NK09	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Loosening of the fuel oil supply piping to the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

[Blank]

Event Description: FO leaked onto the T/C and exhaust gas pipe of No. 1 G/E from the pressure gauge pipe fitted to the FO supply piping, because the copper pipe at compression joint was broken due to vibration, resulting in fire. (Description extracted from Photo 5, page 29, and Figure 12, page 31, of the NK Report).

Event Number:	**Event Characterization**	
NK10	**As Documented in the Event Report**	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of a pressure gauge line (due to vibration) in the fuel oil supply piping to the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 29, 31, 41, and 42.

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Event Description: Not available.

Event Number: NK11	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of piping in the oil cooling system for a fuel oil valve. The valve was for the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Use water instead of oil to provide cooling to the fuel oil valves Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

[Blank]

Event Description: Not available.

Event Number: NK12	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of piping in the oil cooling system for a fuel oil valve. The valve was for the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Use water instead of oil to provide cooling to the fuel oil valves Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

[Blank]

Event Description: Not available.

Event Number: NK13	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of piping in the oil cooling system for a fuel oil valve. The valve was for the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Use water instead of oil to provide cooling to the fuel oil valves Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

[Blank]

Event Description: FO sprayed out from the No.1 cyl. FO valve cooling oil outlet branch pipe of the No.2 G/E because the pipe at the brazing fitting was broken due to vibration and resulted in fire. (Description extracted from Figure 2, page 22, of the NK Report).

Event Number: NK14	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of piping (in way of brazing fitting) in the oil cooling system for a fuel oil valve. (The fuel oil valve was for the generator engine.) The stated cause of the breakage was vibration	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Use water instead of oil to provide cooling to the fuel oil valves Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 22, 41, and 42.

[Blank]

Event Description: FO sprayed out from the FO strainer differential pressure gauge pipe of No. 2 G/E, because the end cover of the inlet air suction manifold hit the pipe due to an explosion in the manifold resulting from an abnormal condition of the air inlet valve of No. 2 G/E, resulting in fire. (Description extracted from Photo 1, page 23, of the NK Report).

Event Number: NK15	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of a differential pressure gauge line for a generator engine strainer. The breakage was caused by an explosion of an air inlet pipe	
Ignition Source		Explosion and/or hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred

[a] NK Report, pages 15, 16, and 23.

[Blank]

Event Description: Not available.

Event Number: NK16	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Loosening of a flange in the fuel oil injection pump for the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[a] NK Report, pages 15, 16, 41, and 42.

[Blank]

Event Description: Not available.

Event Number: NK17	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Malfunction of the boiler burner, resulting in furnace explosion. The furnace explosion damaged flexible joints in the fuel oil system and caused the fire	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The flexible joints used in fuel oil pipes of the boiler burner must be positioned so that they are not subject to secondary damage due to an explosion in the furnace To prevent explosion in the furnace, the burner nozzle must be appropriately serviced and the furnace pre-purged prior to combustion	

[a] NK Report, pages 15, 16, and 43.

[Blank]

Event Description: Not available.

Event Number: NK18	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Malfunction of the boiler burner, resulting in furnace explosion. The furnace explosion damaged flexible joints in the fuel oil system and caused the fire	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The flexible joints used in fuel oil pipes of the boiler burner must be positioned so that they are not subject to secondary damage due to an explosion in the furnace To prevent explosion in the furnace, the burner nozzle must be appropriately serviced and the furnace pre-purged prior to combustion	

[a] NK Report, pages 15, 16, and 43.

[Blank]

Event Description: Not available.

Event Number: NK19	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Malfunction of the boiler burner, resulting in furnace explosion. The furnace explosion damaged flexible joints in the fuel oil system and caused the fire	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The flexible joints used in fuel oil pipes of the boiler burner must be positioned so that they are not subject to secondary damage due to an explosion in the furnace To prevent explosion in the furnace, the burner nozzle must be appropriately serviced and the furnace pre-purged prior to combustion	

[a] NK Report, pages 15, 16, and 43.

[Blank]

Event Description: Not available.

Event Number: NK20	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Malfunction of the boiler burner, resulting in furnace explosion. The furnace explosion damaged flexible joints in the fuel oil system and caused the fire	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The flexible joints used in fuel oil pipes of the boiler burner must be positioned so that they are not subject to secondary damage due to an explosion in the furnace To prevent explosion in the furnace, the burner nozzle must be appropriately serviced and the furnace pre-purged prior to combustion	

[a] NK Report, pages 15, 16, and 43.

[Blank]

Event Description: Not available.

Event Number: NK21	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Malfunction of the boiler burner, resulting in furnace explosion. The furnace explosion damaged flexible joints in the fuel oil system and caused the fire	
Ignition Source		Hot surface and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion		Assumed loss of propulsion
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The flexible joints used in fuel oil pipes of the boiler burner must be positioned so that they are not subject to secondary damage due to an explosion in the furnace To prevent explosion in the furnace, the burner nozzle must be appropriately serviced and the furnace pre-purged prior to combustion	

[a] NK Report, pages 15, 16, and 43.

[Blank]

Event Description: DO sprayed out from the DO supply pipe of the aux. boiler top firing burner because the union fitting in the pipe had become loose and disconnected due to vibration, resulting in fire. DO leaked after disconnection of threaded joint. (Description extracted from Figure 15, page 37, and Photo 21, page 38, of the NK Report).

Event Number:	Event Characterization	
NK22	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Loosening (due to vibration) of a threaded pipe connection in the diesel oil supply piping to the boiler	
Ignition Source		Hot surface, autoignition, and/or open flame
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	The joints of burners of the top firing boiler and fuel oil supply piping (including fuel oil supply pipes for the pilot burner) shall be flexible joints Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment	

[a] NK Report, pages 15, 16, 37, 38, 41, 42, and 43.

[Blank]

Event Description: Not available.

Event Number: NK23	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Breakage of a glass level gauge in the fuel oil tank	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation On fuel oil tanks, oil level gauges made of glass shall, in principle, be prohibited	

[a] NK Report, pages 15, 16, 41, 42, and 44.

[Blank]

Event Description: Not available.

Event Number: NK24	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Diesel oil overflow from the waste oil tank	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Air vent pipes fitted to the fuel oil tank shall not open into the engine room	

[a] NK Report, pages 15, 16, 41, 42, and 44.

[Blank]

Event Description: Not available.

Event Number: NK25	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	Overflow of fuel oil through an air vent pipe in the service tank for the auxiliary boiler	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Air vent pipes fitted to the fuel oil tank shall not open into the engine room	

[a] NK Report, pages 15, 16, 41, 42, and 44.

[Blank]

Event Description: During replenishment of the double bottom diesel oil tank in the engine room, the self-closing valve of the short sounding pipe in the vicinity of the lower floor was left open. The inflammable gas generated from the fuel oil occupied the lower floor space, came into contact with a source of fire and ignited. (Description provided for "Ship A," page 57, of the NK Report.)

Event Number:	Event Characterization	
NK26	As Documented in the Event Report	As Inferred from the Event Report
System/Location[a]	Fuel oil/engine room	
Cause[a]	Vapors escaped through the tank short sounding pipe. The self-closing valve for the short sounding pipe, which is required to be installed according to regulations, was not functioning effectively because it was open for measurement of tank sounding	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred

Event Number NK26 (cont'd)

Event Number: NK26	Event Characterization: As Documented in the Event Report	Event Characterization: As Inferred from the Event Report
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation The short sounding pipe of a double bottom fuel oil tank must be located at a safe distance from potential sources of ignition. Alternatively, appropriate spray shield may be used Use short sounding pipe device that retains air tightness even during measurements. Alternatively, use level gauges instead of conventional sounding methods Periodically inspect the short sounding pipe and air vent pipes on oil tanks to ensure that all equipment (self-closing mechanisms, valves, caps, etc.) is properly aligned and the air vent pipes are not clogged	

[a] NK Report, pages 15, 16, 41, 42, and 57.

Event Description: After replenishing the double bottom diesel oil tank under the boiler, the oil remaining in the piping system was air purged by the bunker supply ship. At this stage, because the short sounding pipe of this tank was open, fuel oil gushed out, came into contact with high temperature parts of the burner furnace directly above the tank, and the electrical equipment in the vicinity, and ignited. (Description provided for "Ship B," page 57, of the NK Report.)

Event Number:	Event Characterization	
NK27	**As Documented in the Event Report**	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	After replenishment, the oil remaining in the piping system was purged by air, although the air space in the tank was not adequate. This caused the fuel oil to gush out of the short sounding pipe The self-closing valve for the short sounding pipe, which is required to be installed according to regulations, was not functioning effectively because the sounding tape had been left in the sounding pipe	
Ignition Source	Hot surface and electrical equipment	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred

Event Number NK27 (cont'd)

Event Number: NK27	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Fuel oil tanks should not be filled above 90% to 95% of the tank's capacity The short sounding pipe of a double bottom fuel oil tank must be located at a safe distance from potential sources of ignition. Alternatively, appropriate spray shield may be used Use short sounding pipe device that retains air tightness even during measurements. Alternatively, use level gauges instead of conventional sounding methods Periodically inspect the short sounding pipe and air vent pipes on oil tanks to ensure that all equipment (self-closing mechanisms, valves, caps, etc.) is properly aligned and the air vent pipes are not clogged	

[a] NK Report, pages 15, 16, 41, 42, and 57.

Event Description: Not available.

Event Number: NK28	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location°	Fuel oil/engine room	
Cause°	Fuel oil spray caused by damage to the generator engine connecting rod	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred

° NK Report, pages 15 and 16.

[Blank]

Event Description: Not available.

Event Number: NK29	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location°	Fuel oil/engine room	
Cause°	Fuel oil spray caused by damage to the generator engine connecting rod	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred

[Blank]

Event Description: Not available.

Event Number: NK30	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[b]	Fuel oil/engine room	
Cause[b]	Improper assembly of a purifier caused spray of diesel oil	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[b]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

[Blank]

Event Description: LO sprayed out from the LO supply pipe for the No. 1 cyl. exhaust valve driving gear of the M/E, because the pipe at the threaded fitting for the stop valve became loose and was disconnected due to vibration, resulting in fire. (Description extracted from Figure 4, page 24, of the NK Report).

Event Number: NK31	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[d]	Lube oil/engine room	
Cause[d]	Loosening of a lube oil supply pipe to the driving gear for an exhaust valve in the main engine. Vibration caused the loosening of the pipe	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[d]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment	

[Blank]

Event Description: LO leaked and fire broke out after disconnection of nylon hose. (Description extracted from Figure 16, page 39, of the NK Report).

Event Number: NK32	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[P]	Lube oil/engine room	
Cause[P]	Disconnection of a lube oil supply pipe to the push rod and rocker arm for an exhaust valve in the main engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[P]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment	

[P] NK Report, pages 15, 16, 39, 41, and 42.

[Blank]

Event Description: Not available.

Event Number: NK33	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[q]	Lube oil/engine room	
Cause[q]	Crankcase explosion in the main engine	
Ignition Source		Explosion
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence	No preventive action mentioned	Not inferred

[q] NK Report, pages 15, 16, and 41.

[Blank]

Event Description: While underway, oil leaked out from the cover of the secondary lubricating oil strainer (H type duplex strainer) for the main engine in the lower floor, dispersed, came in contact with the high temperature parts of the main engine turbocharger and caught fire. The O-ring for the strainer cover of the lubricating oil secondary strainer was removed by a crew member and was damaged while restoring it, therefore, oil leaked out from the cover and dispersed. (Description provided for "Ship B," page 64, of the NK Report).

Fire broke out from a hot-point on the T/C of the M/E because LO leaked from the LO 2nd strainer of the M/E due to the strainer cover becoming loose. (Description extracted from Photo 14, page 34, of the NK Report).

Event Number: NK34	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[r]	Lube oil/engine room	
Cause[r]	The O-ring for the strainer cover of the lubricating oil secondary strainer was removed by a crew member and was damaged while restoring it; therefore, oil leaked out from the cover and dispersed	
Ignition Source	Hot surface (turbocharger for the main engine)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Two crew members died	Not inferred
Corrective Action to Prevent Recurrence[r]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

[r] NK Report, pages 2, 15, 16, 34, 41, 42, and 64.

[Blank]

Event Description: Not available.

Event Number: NK35	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[b]	Lube oil/engine room	
Cause[b]	Loosening of a thermometer fitting in the lube oil cooler for the generator engine	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[b]	Sheath or cover piping, including fittings and flanges, in the fuel oil and lube oil systems Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation Periodically inspect fuel oil/lube oil piping and associated equipment Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil Sheath hot surfaces in the engine room	

[Blank]

Event Description: Not available.

Event Number: NK36	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[b]	Lube oil/engine room	
Cause[b]	Overflow from the lube oil storage tank for the main engine turbo charger	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[b]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

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Event Description: While underway, the lubricating oil strainer of the main engine turbocharger was being operated, and oil spilled out from the changeover cock retaining cover onto the exhaust gas pipe and caught fire. During the changeover operation for the lubricating oil duplex strainer of the turbocharger, the mounting bolts of the packing retaining cover were loosened excessively, resulting in oil leaking from the cover. (Description provided for "Ship C," page 64, of the NK Report.)

The mounting bolts of the cover retaining the packing in the changeover cock were loosened excessively during operation of the duplex L.O. strainer for T/C, with the result that the L.O. gushed out from the cover, and caught fire. (Description extracted from Figure 29, page 66, of the NK Report.) LO sprayed out from the T/C strainer, because the fitting bolts of the packing retaining cover of the change-over cock became loose during operation, resulting in fire. (Description extracted from Photo 19, page 36, of the NK Report.)

Event Number:	Event Characterization	
NK37	As Documented in the Event Report	As Inferred from the Event Report
System/Location[s]	Lube oil/engine room	
Cause[s]	During the changeover operation for the lubricating oil duplex strainer of the turbocharger, the mounting bolts of the packing retaining cover were loosened excessively, resulting in oil leaking from the cover	
Ignition Source	Hot surface (exhaust gas pipe)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty[s]	One fatality	
Corrective Action to Prevent Recurrence[s]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

[s] NK Report, pages 15, 16, 36, 41, 42, 64, and 66.

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Event Description: While underway, the lubricating oil strainer of the generator engine was kept open. After cleaning, and while the air was being purged from the strainer, oil spilled out of the air cock, came into contact with a source of ignition, and caught fire. Carelessness during an air purging operation of the lubricating oil strainer or inappropriate position of the drain opening of the air pipe. (Description provided for "Ship A," page 64, of the NK Report).

Event Number: NK38	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[t]	Lube oil/engine room	
Cause[t]	Carelessness during an air purging operation of the lubricating oil strainer or inappropriate position of the drain opening of the air pipe	
Ignition Source		Hot surface
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred
Corrective Action to Prevent Recurrence[t]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation	

[t] NK Report, pages 15, 16, 41, 42, and 64.

[Blank]

Event Description: During replenishment of fuel oil in the ballast condition and with a trim by the stern, fuel oil gushed out from the short sounding pipe of the double bottom fuel oil tank in the engine room. It came into contact with the exhaust gas pipe of the generator engine while it was running, and caught fire. (Description provided for "Ship C," page 57, of the NK Report.)

Event Number: NK39	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location[a]	Fuel oil/engine room	
Cause[a]	The air pipe of the double bottom fuel oil tank at the aft end of the tank was blocked before the replenishment of fuel oil was completed. This resulted in the air in the tank being compressed, which caused fuel to gush out through the short sounding pipe The cap at the top of the short sounding pipe had been removed. The weight for the sounding pipe cock, which has a self-closing action, had also been removed	
Ignition Source	Hot surface (exhaust gas pipe)	
Detection	Not stated	Not inferred
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Not stated	Not inferred

Event Number NK39 (cont'd)

Event Number: NK39	**Event Characterization** — **As Documented in the Event Report**	**As Inferred from the Event Report**
Corrective Action to Prevent Recurrence[a]	Sheath hot surfaces in the engine room Ensure that protective covers, shielding, insulation, and/or sheathing are in place during normal operation The short sounding pipe of a double bottom fuel oil tank must be located at a safe distance from potential sources of ignition. Alternatively, appropriate spray shield may be used Use short sounding pipe device that retains air tightness even during measurements. Alternatively, use level gauges instead of conventional sounding methods Periodically inspect the short sounding pipe and air vent pipes on oil tanks to ensure that all equipment (self-closing mechanisms, valves, caps, etc.) is properly aligned and the air vent pipes are not clogged	

APPENDIX E

TSB Events and Associated Event Trees/Event Characterization Tables

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This attachment presents the analysis of events investigated and documented by the Transportation Safety Board (TSB) of Canada.[a] We reviewed the titles of dozens of TSB reports (published in the last two decades) on marine-related accidents to identify those that involved fire on board vessels. All fire-related reports were then reviewed to identify incidents involving spray of flammable or combustible liquids on board vessels (a total of only two incidents). Our analysis of these incidents is presented in three parts for each incident:

- The incident description, as documented in the TSB report (we have not edited or modified these descriptions)
- An event tree, which shows the sequence of events associated with the incident
- An event characterization table, which supplements the event tree with comments (as documented in or as inferred from the TSB description) about the system/location, cause, ignition source, means of detection, means of release isolation, means of fire suppression, impact on propulsion, impact on steering, human casualty, and corrective action

[a]Copies of the TSB reports can be downloaded directly from the TSB web site (http://bst-tsb.gc.ca/marinelist.html).

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Event (TSB01) Description:[b] On 07 June 1994, as the fishing vessel "RALI II" was returning from the fishing grounds, a fire broke out in the engine-room. The flames were quickly suppressed by the gas smothering system. However, the resulting electrical power failure caused the vessel to begin to make sternway, which could not be stopped, thereby complicating any attempt at abandonment. There were no injuries as a result of this occurrence, but the engine-room sustained considerable damage.

A drop in the pressure of the fuel supply to the main engine led the engine-room personnel to try to change the main filters. They turned off the three-way valve to isolate one of the two filters (duplex type) and began to unscrew the cover without first lowering the internal pressure using the drain plug. As the diesel fuel was escaping with no drop in pressure, they tried to re-tighten the cover. As they were doing this, the center post of the filter broke. The cover lifted off and diesel fuel sprayed on to the exhaust pipes of the main engine and caught fire.

Inspection of the failed component revealed that it had been welded previously. No one remembered when this repair had been made. Inspection of the main filters revealed that the overflow valve on the unit that the engine-room personnel was trying to open was damaged and not operational. The ball held on its seat by a spring which prevents diesel fuel from flowing back toward the filter was missing. The seat was so worn that the ball slipped through. The day tank is located above the level of the main filters.

The fuel filters were installed on the front of the engine, near the turbocharger and the exhaust pipe. No splash-guard was fitted to prevent diesel fuel from splashing on to the engine. The cover of the filter was loosened without first emptying the filter. The drop in the pressure of the fuel supply system was not due to dirty filters but to the failed overflow valve which allowed the diesel fuel to flow back freely to the day tank.

The engine-room was immediately evacuated, the propeller pitch was set at zero, the engine speed was reduced to slow, the engine-room openings were closed, and the CO2 gas smothering system was activated. An electrical power failure followed the activation of the gas smothering system. Shortly thereafter, the vessel began gradually to make sternway, dragging in her wake first one life raft that had already been launched and then a second one that the crew had tried to launch under unfavorable conditions. The rafts were damaged, and the survival equipment they contained was lost.

The controls of the main engine were set at the lowest revolutions per minute (RPM). All attempts to disengage the propeller shaft or to stop the engine with the emergency stop button were unsuccessful. The remote controls to shut off the four diesel fuel tanks were activated, but the valve of the day tank did not close.

The "RALI II" continued making sternway for approximately one and a half hours. There were no injuries as a result of the fire, but the engine-room was damaged. The damage, caused mainly by the smoke and heat given off by the fire, was confined to the engine-room. The electrical wires running overhead in the engine-room over the source of the fire were severely damaged.

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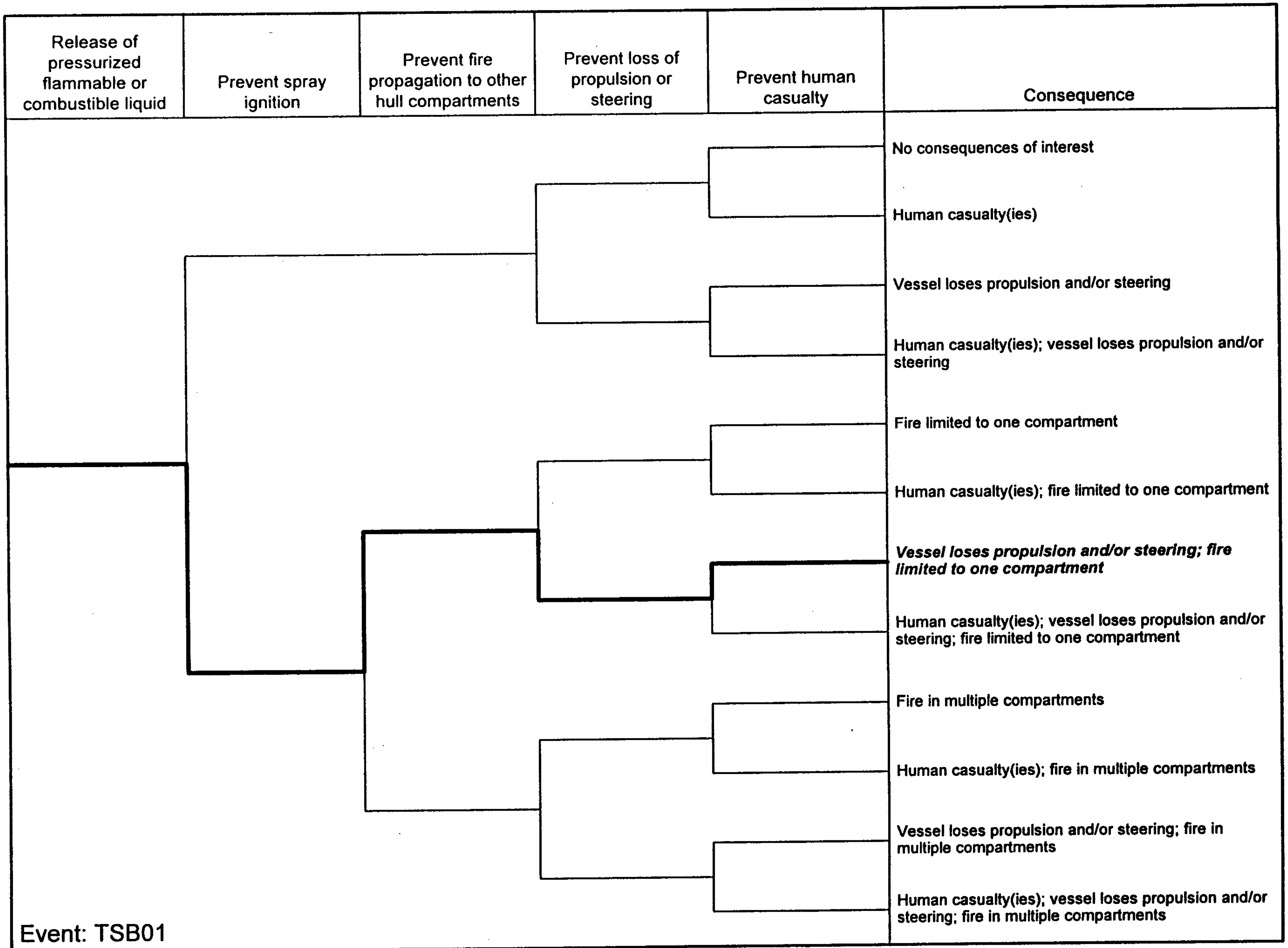
[b]Description extracted from "Report m94m0020" and "Synopsis m94m0020," both available from the TSB web site.

The Board determined that the fire broke out when a component of the main fuel filters of the main engine failed and the engine-room personnel undertook to clean the filters. This component failure, combined with an improper work method, caused diesel fuel to splash on to the unprotected exhaust pipes. During the fire, the main engine emergency stop remote control and that of the propeller shaft clutch mechanism failed to work.



Revised 02/18/98 at 08:58

Event Number: TSB01	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Fuel oil/engine room	
Cause	The TSB determined that the fire was caused by equipment failure and improper work method While changing main filters, the crew turned off the three-way valve to isolate one of the two filters (duplex type) and began to unscrew the cover *without first lowering the internal pressure using the drain plug.* Diesel fuel started to escape with no drop in pressure, and the crew tried to re-tighten the cover. As they tried to re-tighten the cover, the center post of the filter broke, lifting the cover and spraying diesel fuel The failed post had been welded previously. Also, the reason that the pressure did not drop was because the seat of the overflow valve was worn, allowing the ball to slip through	
Ignition Source	Hot surface (unprotected exhaust pipe)	
Detection		Crew
Release Isolation	Unsuccessful. During the fire, the main engine emergency stop remote control and that of the propeller shaft clutch mechanism failed to work No attempt was made to stop the main engine before the vessel began to make sternway, although this vessel, fitted with a controllable-pitch propeller, was known to make sternway following a power failure	
Fire Suppression	CO_2 system	

Event Number TSB01 (cont'd)

Event Number: TSB01	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
Impact on Propulsion	Vessel made sternway for approximately 1½ hours	
Impact on Steering	Vessel made sternway for approximately 1½ hours	
Human Casualty	None	
Corrective Action to Prevent Recurrence	The shield plate for the main engine exhaust pipe, which had been removed during previous maintenance work, has been put back in place A steel guard plate has been fitted to provide an additional safeguard near the fuel filters The filters have been replaced by new parts and relocated approximately 2 meters away from the main engine exhaust manifold and piping	

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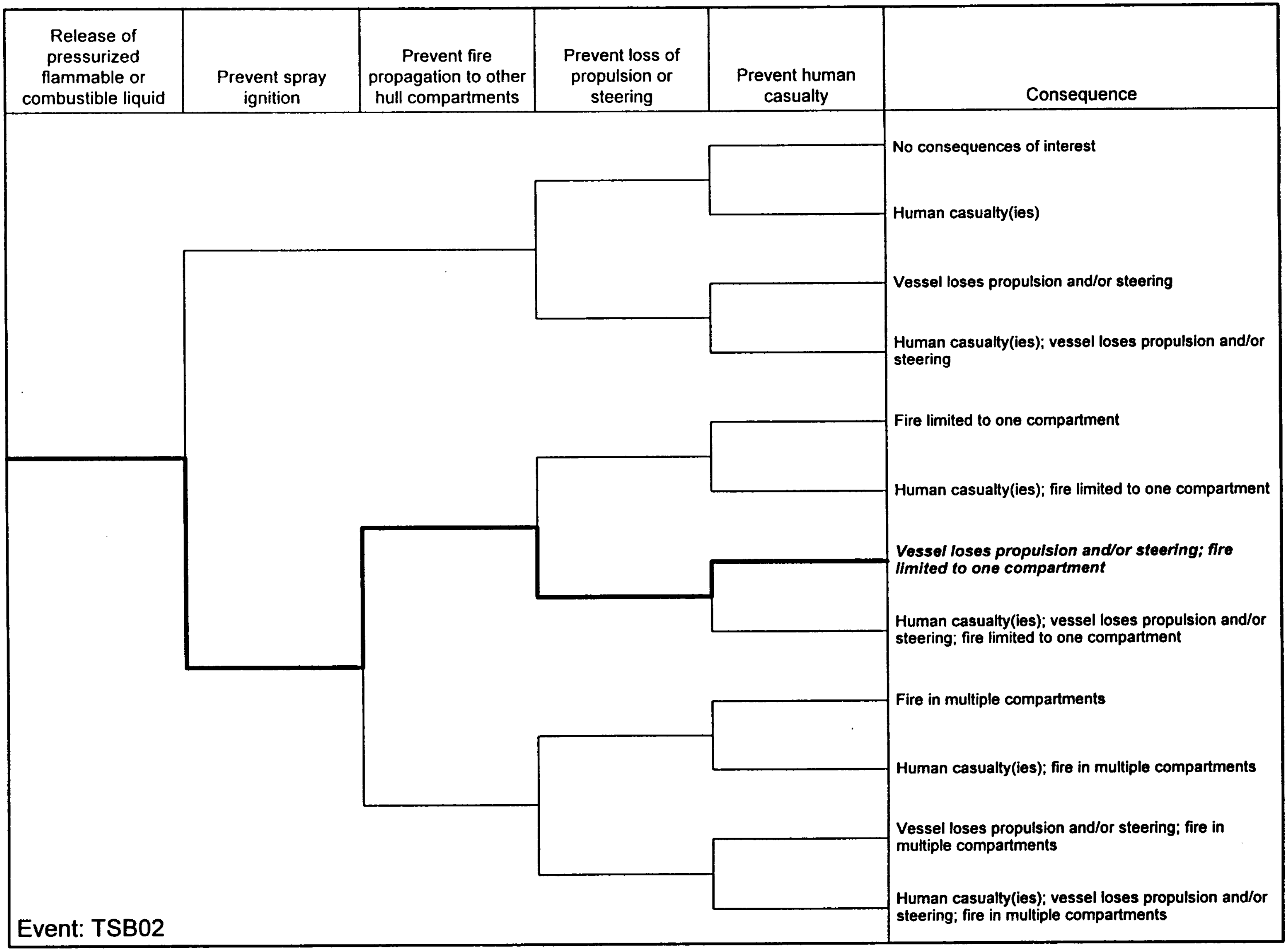
Event (TSB02) Description:[c] The "JUDITH SUZANNE" departed Liverpool, Nova Scotia, on 17 September 1993, on what was intended to be a 10-day scallop fishing trip to the Georges Bank fishing grounds. At about 1230, 18 September, the master, who was on the bridge, smelled smoke. As he was about to investigate, a bang or minor explosion was heard from the direction of the engine-room followed quickly by the alarm indicating the imminent activation of the carbon dioxide (CO2) automatic fire-extinguishing system in the engine-room. Shortly before the alarm sounded, considerable electrical interference had been heard on a radio receiver. The vessel was stopped by using the wheel-house controls to take the main engine out of gear, and the CO2 cylinder storage area was checked to ensure that the cylinder had discharged properly.

There was only one access door to the engine-room. When it was opened to assess the situation, it could be seen that the fire was not fully extinguished. Two portable fire extinguishers were directed through the doorway at the seat of the fire which was observed to be in the area of the starboard generator. The smoke and flames were rapidly intensifying and preventing anyone from entering the engine-room to fight the fire; therefore, the engine-room door was closed so that the fire might extinguish itself through a lack of oxygen. The remote fuel shut-off valve was closed to stop the main engine and prevent fuel from feeding the fire.

It soon became apparent that the fire was out of control and the two inflatable life rafts were launched. Because of the increasing intensity of the fire and because there was no other means of fighting it, the decision was made to abandon the "JUDITH SUZANNE" and board the life rafts. The weather conditions were good with light airs and a slight sea and, despite fog restricting the visibility, the crew members were safely picked up by another fishing vessel about 20 minutes after casting off from the "JUDITH SUZANNE".

The fire started in the engine-room, in the area in which the starboard generator and the boiler were located, but there was no conclusive evidence which would suggest that one of these two pieces of machinery may have been the cause of the fire. The electrical interference heard on the radio might suggest a malfunction of the generator's electrical components, and the explosion could be symptomatic of a problem with the furnace or a problem in the crankcase of the generator. However, sparking or a loose connection in any electrical circuit could have caused the electrical interference. The evidence was that the smoke could be smelled, and the fire had probably therefore started, before the explosion occurred. There was no other evidence linking the start of the fire to either the generator or the boiler; the precise cause of the fire was thus not determined.

[c]Description extracted from "Report m93m0005" and "Synopsis m93m0005," both available from the TSB web site.



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Event Number: TSB02	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Undetermined/engine room	
Cause	Undetermined. The fire started in the engine room, in the area in which the starboard generator and the boiler were located, but there was no conclusive evidence suggesting that one of these two pieces of machinery may have been the cause of the fire	
Ignition Source	Not stated	Not inferred
Detection	Crew	
Release Isolation	The remote fuel shut-off valve was closed to stop the main engine and prevent fuel from feeding the fire	
Fire Suppression	Unsuccessful (the vessel eventually sank). The CO_2 system for the engine room actuated, but it did not put out the fire	
Impact on Propulsion	Loss of propulsion	
Impact on Steering		None
Human Casualty	None	
Corrective Action to Prevent Recurrence	Formal training in marine emergency duties, including lifesaving equipment and survival techniques	

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APPENDIX F

MIIU Events and Associated Event Trees/Event Characterization Tables

The Marine Incident Investigation Unit (MIIU), headed by the Inspector of Marine Accidents, Australia, investigates marine incidents as defined by the Australian navigation (marine casualty) regulations, including incidents involving:

1. Loss of life or serious injury aboard ship
2. Loss of a ship
3. Fires, collisions, groundings, and the disabling of a ship
4. Damage to, or caused by, ships
5. Serious damage to the environment caused by a ship or incidents where any of the above might reasonably have occurred

The purpose of an MIIU investigation is to identify the circumstances of an incident and determine its causes. All reports of investigations are published to make the causes of an accident known within the industry, so as to help prevent similar occurrences. In making findings as to the cause of a particular incident, it is not the function of the MIIU to attribute blame or determine liability.

This attachment presents the analysis of selected events documented by MIIU[a] for the last two decades. We reviewed the titles of all MIIU reports on marine-related accidents to identify those that involved fire on board. These selected reports were then reviewed to identify those that documented fires in the engine room involving either fuel oil or lube oil systems (a total of only three incidents).[b] Our analysis of these incidents is presented in three parts for each incident:

- The incident description, as documented in the MIIU report (we have not edited or modified these descriptions)
- An event tree, which shows the sequence of events associated with the incident
- An event characterization table, which supplements the event tree with comments (as documented in or as inferred from the MIIU description) about the system/location, cause, ignition source, means of detection, means of release isolation, means of fire suppression, impact on propulsion, impact on steering, human casualty, and corrective action

[a]Copies of the MIIU reports can be downloaded directly from the MIIU web site (http://www.miiu.gov.au/miiuhome.htm).

[b]The investigation of fires on board the Australian-flagged Goliath (Devenport, August 23, 1997) and the Taiwanese flag Ming Mercy (Port Kembla, August 7, 1997) is still being conducted, and the investigation reports have not yet been released. We do not know whether these fires involved fuel oil or lube oil systems in the engine room; these incidents are not considered in this attachment.

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Event (MIIU01) Description: On 3 February 1995 the Norwegian flag tanker Team Heina was at anchor off Sydney Harbour, waiting to berth at Gore Bay, when, at about 0945, a compression fitting on a line to a fuel pressure gauge on No.3 diesel generator blew out. The resulting spray of hot heavy fuel oil at about 6 bar pressure, ignited on the engine's exhaust manifold and then spread burning oil over the deckhead above the engine. The fire intensified and expanded rapidly.

Most of the engineering department personnel were working around the engine room at the time. The First Engineer ran to the engine control room and shut down the generator before attacking the fire with an extinguisher. The extinguisher, however, failed to discharge. The motorman had grabbed another extinguisher but that, too, failed to discharge. By the time other extinguishers had been brought to the scene and used, the fire had increased to the point where the Chief Engineer decided to evacuate the engine room.

The engine room was evacuated, the vent flaps were closed and the vessel's fixed firefighting system (Halon) was discharged. When it became apparent to the ship's crew, who were making their way to their muster stations on deck, that it was a serious fire, a number of them ran to the port lifeboat.

Ten to fifteen minutes after discharging the Halon, a crew member, wearing breathing apparatus, made a re-entry and reported that some small patches of fire remained. These were put out by two other crew members with portable extinguishers.

The First Engineer, wearing breathing apparatus made an entry and started one of the diesel generators, restoring power to the vessel which had remained blacked out since No.3 generator had been stopped. The emergency generator had started but failed to come on line.

The engine room was ventilated and the damage was assessed. Initially it appeared that the damage was superficial, but closer inspection of the main cable run above No.3 generator revealed that it had suffered some damage. The classification society imposed a condition of class on the vessel, requiring repairs at the next drydocking. Pending repairs, only Nos. 1 and 2 generators could be used.

Conclusions of MIIU team (intended to identify the different factors contributing to the accident and should be not read as apportioning blame or liability to any particular organization or individual):

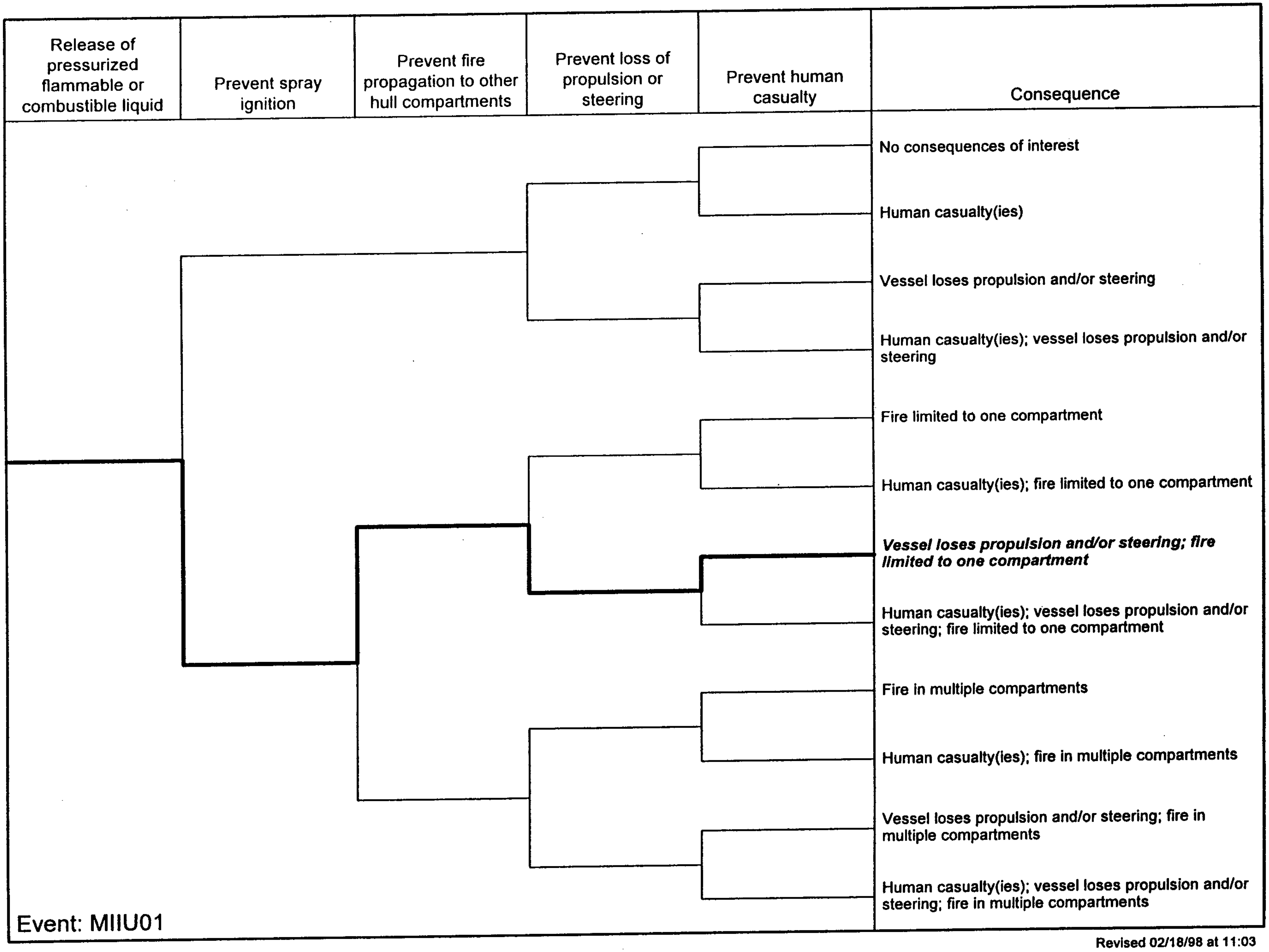
1. The fire in the engine room was caused by a spray of hot fuel oil, from a failed compression fitting on the fuel rail of the starboard generator engine (No.3), being ignited by the hot exhaust manifold.

2. The pipe to the fuel pressure gauge had blown out of the compression fitting following prolonged fretting of the pipe within the olive and of the olive within the compression fitting. The fretting was caused by misalignment of the pipe with the fitting and the added fact that the pipe had probably not been inserted sufficiently far into the olive on initial assembly. The combined effect would have been exacerbated by engine vibration.

3. The actions taken by the ship's staff to fight the fire were correct and the speed with which the preparations for Halon flooding were made was commendable.

4. It is speculative as to whether the failure of the first two dry powder fire extinguishers to discharge had any effect on the overall fire-fighting operations. However, it is not expected that two extinguishers serviced only six days previously, should fail in such a manner. The Inspector considers that the work load and schedule for servicing the ship's fire-fighting equipment by one man was such that the service could not have been sufficiently thorough.

5. The re-entry to the engine room, without breathing apparatus, was made on the assumption that there had been sufficient ventilation for sufficient time. As portable oxygen analyzers are part of the safety equipment carried by tankers, it would have been prudent to have used one to check the atmosphere before the re-entry was made.


Release of pressurized flammable or combustible liquid
Prevent spray ignition
Prevent fire propagation to other hull compartments
Prevent loss of propulsion or steering
Prevent human casualty
Consequence
No consequences of interest
Human casualty(ies)
Vessel loses propulsion and/or steering
Human casualty(ies); vessel loses propulsion and/or steering
Fire limited to one compartment
Human casualty(ies); fire limited to one compartment
Vessel loses propulsion and/or steering; fire limited to one compartment
Human casualty(ies); vessel loses propulsion and/or steering; fire limited to one compartment
Fire in multiple compartments
Human casualty(ies); fire in multiple compartments
Vessel loses propulsion and/or steering; fire in multiple compartments
Human casualty(ies); vessel loses propulsion and/or steering; fire in multiple compartments
Event: MIIU01
Revised 02/18/98 at 11:03

Event Number: MIIU01	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	The pipe to the fuel pressure gauge had blown out of the compression fitting following prolonged fretting of the pipe within the olive and of the olive within the compression fitting. *The fretting was caused by misalignment of the pipe with the fitting and the added fact that the pipe had probably not been inserted sufficiently far into the olive on initial assembly.* The combined effect would have been exacerbated by engine vibration	
Ignition Source	Hot surface (engine exhaust)	
Detection	Crew (most of the engineering department personnel were working around the engine room at the time)	
Release Isolation	Shut down the engine (the First Engineer ran to the engine control room and shut down the generator before attacking the fire with an extinguisher)	
Fire Suppression	The engine room was evacuated, the vent flaps were closed, and the vessel's fixed firefighting system (Halon) was discharged The crew tried to use two handheld extinguishers before they discharged the Halon system, but both extinguishers failed to discharge	
Impact on Propulsion		Loss of propulsion
Impact on Steering		None

Event Number MIIU01 (cont'd)

Event Number: MIIU01	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
Human Casualty		None
Corrective Action to Prevent Recurrence	None suggested in the report	

[Blank]

Event (MIIU02) Description: On 19 April 1994 the New Zealand flag ro-ro vessel Union Rotoma was on passage from Nelson in New Zealand to Port Botany in NSW when, at 1835, alarms were sounded by the vessel's automatic fire detection system indicating a fire in the engine room. The duty engineer quickly reported that the aft end of the port main engine was on fire. The fire was spreading very rapidly and the decision was taken to evacuate the engine room and to flood it with the ship's fixed carbon dioxide extinguishing system. A "Mayday" message was transmitted by Inmarsat C and was acknowledged by the Maritime Rescue Coordination Centre in Canberra.

While the crew were shutting down the engine room, the bulk CO_2 was released. The main engines had been stopped from the bridge. Shortly after the release, the running generator stopped, indicating that it had been stifled by the CO_2. Approximately one and a half hours after the release of CO_2, two engineers wearing breathing apparatus made an inspection of the engine room and reported that the fire had been extinguished and there were no remaining hot spots.

The engine room was purged of CO_2 before a further inspection was made and the generators were started to restore full electrical power.

The inspection revealed that oil, spraying from a fractured pipe on the starboard engine, had ignited on the hot exhaust manifolds of the port engine. The pipe, carrying lubricating oil to the engine's overspeed trip mechanism and to the camshaft bearings, had been fractured by the movement of the camshaft anchor bearing housing moving out of the entablature, into which it had been secured by eight 20mm diameter set bolts, all of which had sheared or worked loose.

Damage caused by the fire was slight, involving mainly instrumentation and wiring. The ship was able to proceed on its voyage to Port Botany using only the port main engine.

Conclusions of MIIU team (intended to identify the different factors contributing to the accident and should be not read as apportioning blame or liability to any particular organization or individual):

1. The fire in the engine room was caused by a spray of lubricating oil, from a fractured pipe on the starboard main engine, being ignited by the hot exhaust manifolds on the port engine.

2. The lubricating oil pipe was fractured when the housing for the camshaft anchor bearing worked its way out of the entablature, consequent upon the failure of the eight securing set bolts.

3. The set bolts which secured the bearing housing in the entablature had no form of locking and should have had cross-drilled heads and been laced with locking wire.

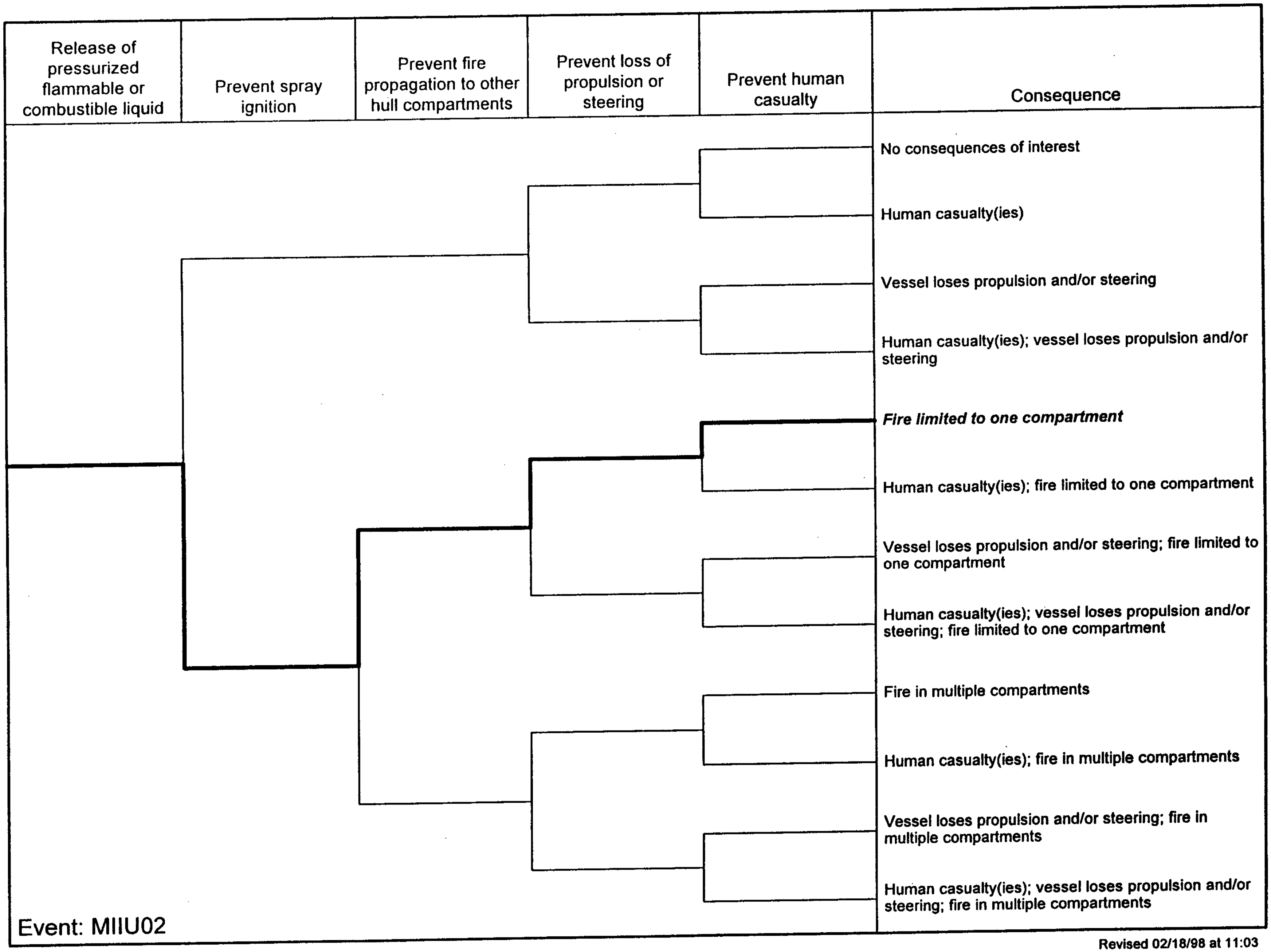
4. It was not possible to ascertain when the securing set bolts had been fitted, but it appears that they must have been fitted when the vessel was in the hands of previous owners. At the time that they were fitted, they were probably not pre-loaded to the required torque.

5. Engine vibration would have contributed to the failure of the bolts.

6. The response of the vessel's firefighting organization was both fast and effective. This was due in large part to the fact that all officers and key personnel had personal UHF radios and excellent communications were maintained between all those involved throughout the incident.

7. Realistic fire drills carried out on a regular basis, incorporating such techniques as using radios while wearing breathing apparatus and scenarios such as engine room fires requiring CO_2 flooding, contributed to the efficiency with which the fire was extinguished.

8. No portable oxygen analyzers were available on board with which to test the atmosphere in the engine room after it had been vented to clear the CO_2. Although not a statutory requirement, had one of these been available it would have minimized the risk to personnel when re-entering a space which had been flooded with CO_2.



Revised 02/18/98 at 11:03

Event Number: MIIU02	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	The lubricating oil pipe was fractured when the housing for the camshaft anchor bearing worked its way out of the entablature, consequent upon the failure of the eight securing set bolts The set bolts that secured the bearing housing in the entablature had no form of locking and should have had cross-drilled heads and been laced with locking wire It was not possible to ascertain when the securing set bolts had been fitted, but it appears that they must have been fitted when the vessel was in the hands of previous owners. At the time that they were fitted, they were probably not preloaded to the required torque Engine vibration would have contributed to the failure of the bolts	
Ignition Source	Hot surface (exhaust manifold)	
Detection	Vessel's automatic fire detection system	
Release Isolation	Crew stopped the main engines from the bridge	
Fire Suppression	Fixed CO_2 system	
Impact on Propulsion	Momentary loss of propulsion, but the ship was able to proceed on its voyage using only the port main engine	
Impact on Steering		None
Human Casualty		None

Event Number MIIU02 (cont'd)

Event Number: MIIU02	**Event Characterization**	
	As Documented in the Event Report	**As Inferred from the Event Report**
Corrective Action to Prevent Recurrence	None suggested in the report	

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Event (MIIU03) Description: In the early hours of 30 November 1991, while on a positioning voyage from Singapore to Cebu City in the Philippines, the Australian registered fishing vessel Northern L caught fire. The six crew were unable to fight the fire and abandoned the vessel in approximate position latitude 8 degrees 03 minutes North, longitude 118 degrees 34 minutes East, taking with them an emergency radio and the vessel's 406mHz emergency position indicator radio beacon (EPIRB). At about 0500 explosions were heard coming from the vessel, which sank shortly after.

At sunrise the crew took stock of their surroundings and activated the vessel's EPIRB. At about 0830, the Australian Marine Rescue Coordination Centre received a distress alert from the United States MRCC, Washington that a distress beacon belonging to the Australian registered fishing boat had been detected in position 8 degrees 02 minutes North 118 degrees 33 minutes East. These details were passed to Westpac MRCC in Japan, and Manila MRCC in the Philippines. At 1130 (UTC+8) the Liberian registered tanker Nagasaki Spirit, en route from Dulang, Malaysia, to Santan, Indonesia, was requested by Westpac MRCC to proceed to a position 08 degrees 03.3 minutes North and 118 degrees 34.3 minutes East to investigate the EPIRB signal. At 1245 the Nagasaki Spirit sighted an orange canopy and by 1340 the six survivors had been taken on board the tanker.

Conclusions of MIIU team (intended to identify the different factors contributing to the accident and should be not read as apportioning blame or liability to any particular organization or individual):

1. The circumstances described and without evidence to the contrary it is concluded that the loss of the vessel was due to fire and the unrestricted flooding of the engine-room and the adjacent spaces below the main deck.

2. It is concluded that the fire originated in the engine-room. It is not possible to determine with certainty the cause of the fire or the reason for the sinking. However, the most likely cause may be attributed to the escape of diesel oil from a fractured fuel line spraying on to a hot machinery surface, igniting the oil and causing intense heat in the confined spaces of the engine-room. Fuel from the bunker fed the fire.

3. The outbreak of fire occurred while the engine-room was unattended. Had the person on watch been in the engine-room the fire would have been detected at an early stage and therefore it is probable that it could have been controlled and extinguished.

4. The supply of air to the fire and the fire's rapid unrestrained spread were the direct result of the engine-room not being isolated from the spaces either side of it or above it. It was accepted practice on board to operate with all doors, watertight or not, open.

5. Access to the remote controls to the engine-room fuel supply, the vessel's ventilation units and the engine-room CO_2 fire smothering system was cut off by the fire, due to the engine-room not being secured and the access to the engine-room at frame 51 being open.

6. It is not possible to determine the source or sources of the explosions reported by the survivors. It is possible that the explosions were as a result of the rupturing of pressure vessels and/or the fuel in the tanks being heated to a level whereby the oil's flash point was reached.

7. Whatever the level of proficiency of the master and crew, the absence of any water on the fire main, compounded by the inability to secure any breathing apparatus, rendered the crew totally unable to fight the fire. Evacuation of the vessel to await the outcome of the fire was their only option.

8. The quality of the operational procedures and standards practiced (or not practiced) aboard the Northern L created the conditions in which accidents were more likely to occur, and where emergencies were more likely to get out of hand.

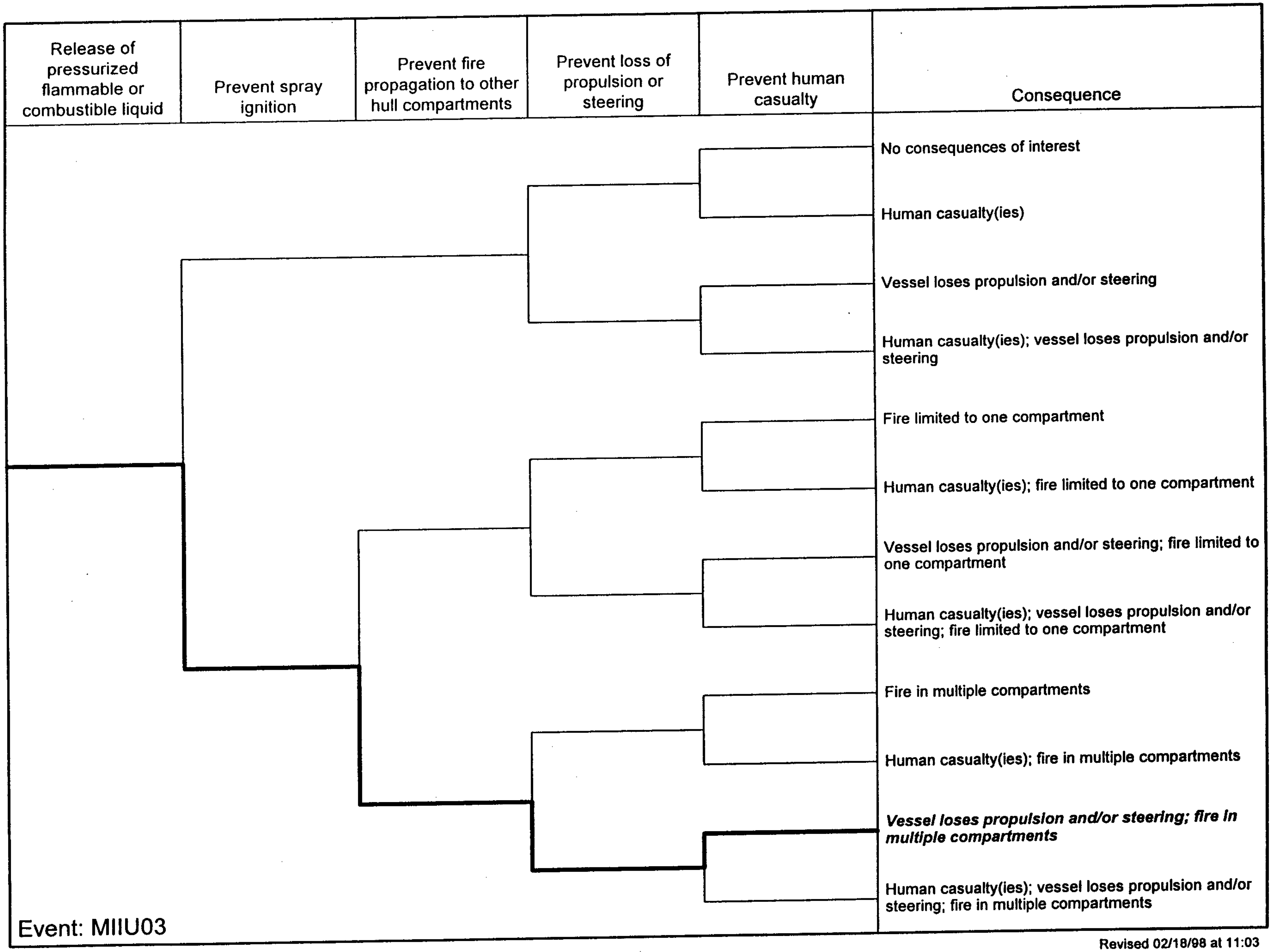
9. The position of the controls for the remote shutting down of the fuel supply from engine-room fuel tanks and the release of the engine-room CO_2 fire smothering system were in accordance with the relevant legislation, notwithstanding that on this occasion access to them was cut off by the fire. However, their position within the enclosed main deck was not an optimum position, given the construction of the upper deck at conversion.

10. If the engine-room door at frame 51 had been removed, or was left open as a standard practice, the remote stops for ventilation and engine-room pumps were positioned contrary to the regulations.

11. The controls for the watertight doors were not above the bulkhead deck, as required by the regulations.

12. The diesel gas oil shipped in Singapore was within the declared specifications.

13. The liaison in 1989, between the Department of Transport and Communications, and subsequently the Australian Maritime Safety Authority, and the American Bureau of Shipping was deficient in ensuring that the converted vessel met the letter or spirit of the Australian regulations in respect of fire control and subdivision.



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Event Number: MIIU03	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Fuel oil/engine room	
Cause	The most likely cause may be attributed to the escape of diesel oil from a fractured fuel line spraying on to a hot machinery surface, igniting the oil and causing intense heat in the confined spaces of the engine room. Fuel from the bunker fed the fire	
Ignition Source	Hot surface	
Detection	Not stated	Not inferred
Release Isolation	Unsuccessful. Access to the remote controls to the engine room fuel supply, the vessel's ventilation units, and the engine room CO_2 fire-smothering system was cut off by the fire	
Fire Suppression	Unsuccessful. Access to the remote controls to the engine room fuel supply, the vessel's ventilation units, and the engine room CO_2 fire-smothering system was cut off by the fire	
Impact on Propulsion	Loss of propulsion (the vessel sank)	
Impact on Steering	Loss of steering (the vessel sank)	
Human Casualty		None
Corrective Action to Prevent Recurrence	None suggested in the report	

APPENDIX G

NTSB/MAR-95/04 Events and Associated Event Trees/Event Characterization Tables

The U.S. National Transportation Safety Board (NTSB) is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, and hazardous materials safety. Established in 1967, the agency investigates transportation accidents, determines the probable cause of accidents, issues safety recommendations, studies transportation safety issues, and evaluates the safety effectiveness of government agencies involved in transportation. NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.[a]

This attachment presents the analysis of selected events documented in Marine Accident Reports (MARs) prepared by the NTSB. We reviewed the titles of more than 100 NTSB reports on marine-related accidents to identify those that involved fire on board ships. These selected reports were then reviewed to identify those that documented fires in the engine room involving either fuel oil or lube oil systems. This attachment presents the analysis of a total of three events involving sprays of flammable or combustible liquids on board ships. Our analysis of these incidents is presented in three parts for each incident:

- The incident description, as documented in the NTSB report (we have not edited or modified these descriptions)
  [Blank]
- An event tree, which shows the sequence of events associated with the incident
- An event characterization table, which supplements the event tree with comments (as documented in or as inferred from the NTSB description) about the system/location, cause, ignition source, means of detection, means of release isolation, means of fire suppression, impact on propulsion, impact on steering, human casualty, and corrective action

[a]Copies of NTSB reports may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. Details on available publications may be obtained by contacting the National Transportation Safety Board, Public Inquiries Section, RE-52, 800 Independence Avenue, S.W., Washington, DC 20594 (Phone: [202] 382-6735). Most of this information is also available from NTSB's web site (http://www.ntsb.gov/Publictn/M_Acc.htm).

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Event (NTSB01) Description: On June 10, 1994, the lubricating oil duplex strainer on the SEAL ISLAND's turbogenerator had a defective O-ring (gasket) that was leaking about 6 gallons of oil daily. To avoid shutting down the ship's service turbogenerator for 2 hours to make a permanent repair to the duplex strainer, the chief engineer devised an assembly comprising an O-ring, a metal cup, and a screw-jack. The cup was to fit around the bottom of the flow valve casing. The screw-jack was to hold the cup in place to achieve and maintain a tight fit. When the first engineer tried to attach the O-ring and cup, the valve's lower securing pin prevented his getting a tight seal. The chief engineer directed him to retract the lower securing pin ... the replacement chief engineer cautioned that it was dangerous to remove the pin without having a device to hold the flow valve in place. The chief engineer designed a strongback, which was fabricated by a machinist in about 10 hours. On June 12, all four components of the temporary assembly were fitted on the oil strainer and the oil leak stopped. (Description extracted from Figures 2, 3, and 4, pages 2 and 3, of the NTSB/MAR-95/04 report.[b])

On October 8, 1994, the Liberian tankship SEAL ISLAND was moored at the Hess Oil Refinery in St. Croix, U.S. Virgin Islands. About 0845, while engineering personnel were changing the lubricating oil strainer on the ship's service turbogenerator, lubricating oil sprayed onto the hot turbine casing and a fire erupted. The fire burned about 6 hours before it was extinguished. (Description extracted from page v of the NTSB/MAR-95/04 report.)

The fire resulted in the death of three crewmembers and serious injury of six other crewmembers. The fire seriously damaged the tankship's engineroom; heat, smoke, water, and soot badly damaged the accommodations and pilothouse. The tankship was declared "no longer a useful carrier" and its owner, the Seal Island Shipping Corporation, had it towed to Spain where it was sold as scrap for $12 million. (Description extracted from page v of the NTSB/MAR-95/04 report.)

The National Transportation Safety Board determines that the probable cause of the fire on board the SEAL ISLAND was the chief engineer's failure to recognize the risks introduced by the temporary repair to the engineroom oil strainer. Contributing to the loss of life were the suddenness and severity of the fire, the inability of the crew to use the control room emergency escape hatch, and the lack of fire and escape drills in the vessel engineroom. (Description extracted from page v of the NTSB/MAR-95/04 report.)

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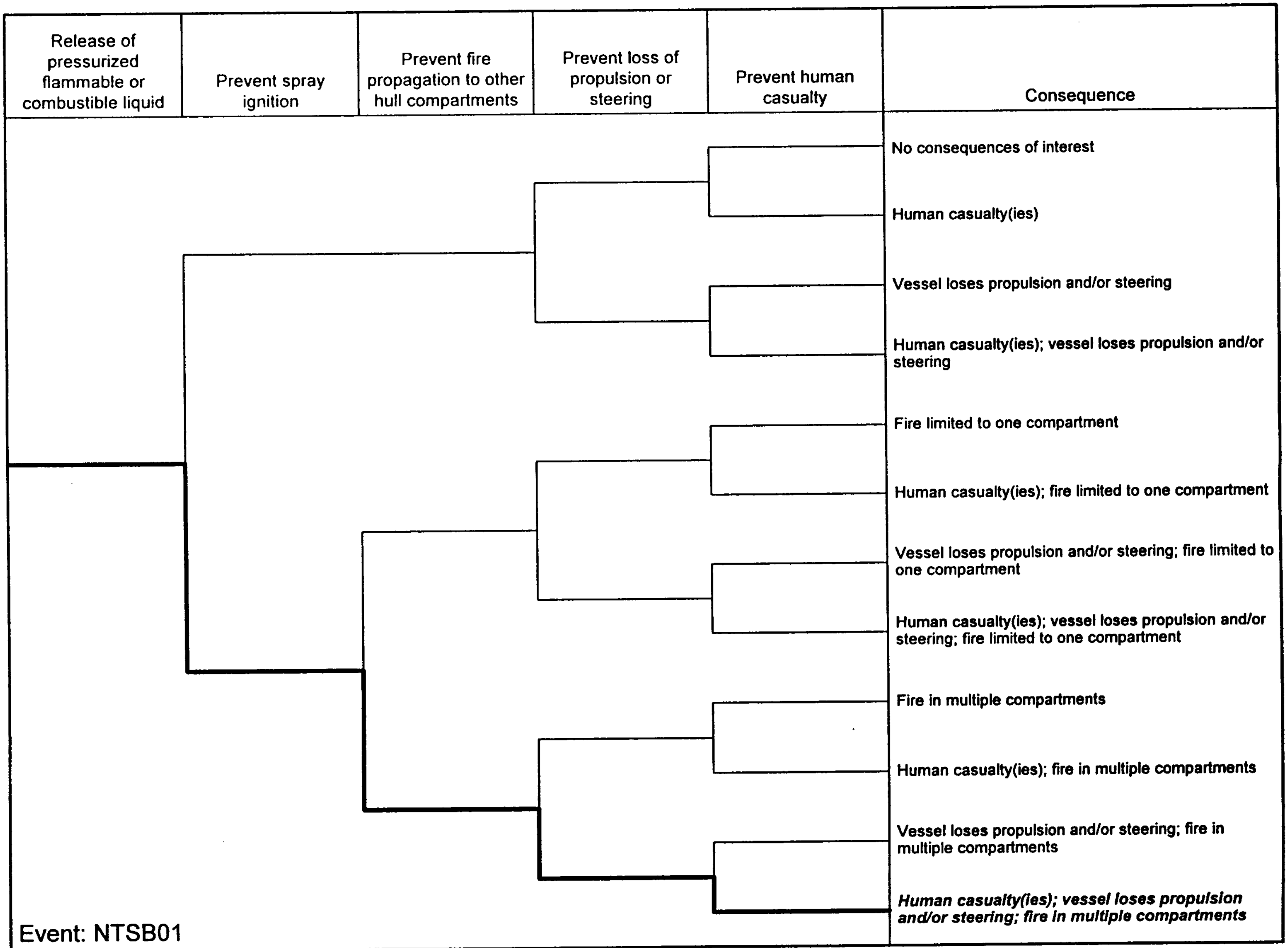
[b]National Transportation Safety Board, *Marine Accident Report – Engineroom Fire On Board the Liberian Tankship SEAL ISLAND While Moored at the Amerada Hess Oil Terminal in St. Croix, U.S. Virgin Islands, October 8, 1994*, NTSB/MAR-95/04, December 1995.



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Event Number: NTSB01	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Lube oil/engine room	
Cause[c]	On October 8, 1994, the crew removed the strongback on the lubricating oil duplex strainer to replace the strainer element on the aft strainer. After replacing the element, the crew moved the directional flow control valve handle to the aft basket. Lube oil suddenly sprayed upward from the duplex strainer The reason for the spray was that the lower securing pin for the flow control valve had been removed to install a temporary assembly to stop a leak. A strongback kept the flow control valve in place during normal operation, but it had to be removed to replace the strainer element. Changing the strainer element without a device in place to restrain the upward movement of the control valve was poorly thought out and created a hazard that ultimately led to the fire	
Ignition Source	Hot surface (turbogenerator casing)	
Detection	Crew	
Release Isolation	The turbine tripped automatically on low lubricating oil pressure	
Fire Suppression	Unsuccessful	
Impact on Propulsion	Loss of propulsion (the ship had to be towed)	
Impact on Steering		None

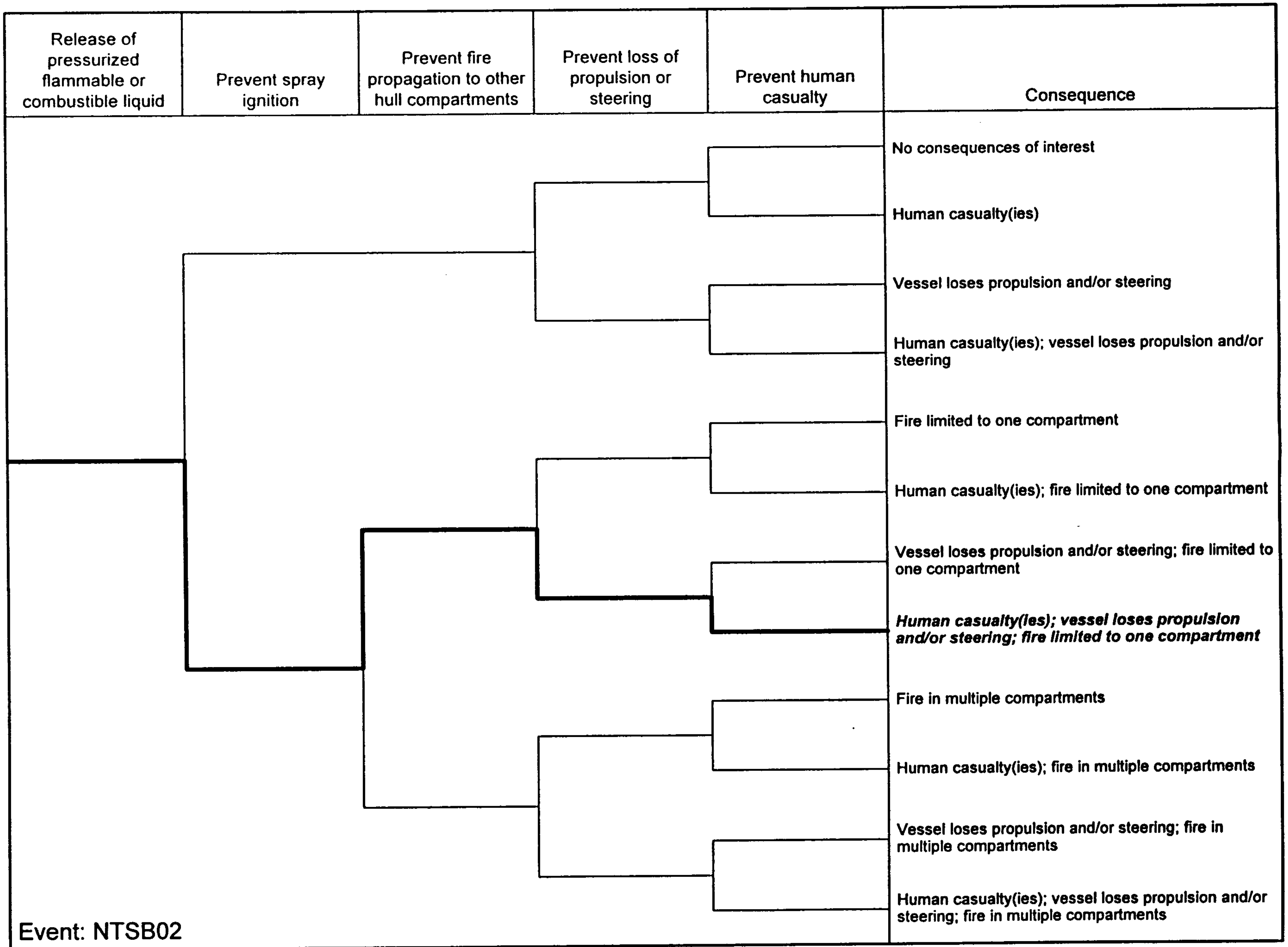
Event NTSB01 (cont'd)

Event Number: NTSB01	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
Human Casualty	Three fatalities and six serious injuries[d] When the fire started, nine people were in the engine room. The first engineer, an electrician, and a machinist died. All six survivors suffered burn and inhalation injuries during their escape	
Corrective Action to Prevent Recurrence[c, e]	All ships maintain readily accessible emergency breathing apparatus to facilitate escape from the engine room Periodic engine room fire and escape drills International Maritime Organization should develop a standard for engine room fire and escape drills that will include, at a minimum, how to locate and don breathing apparatus and how to find and use emergency exits in simulated fire conditions Test all modes of fire pump starting systems, including electric, hydraulic, and pneumatic, during fire and boat drills Install spray shields around lubricating and fuel oil strainers	

[c]NTSB/MAR-95/04 report, pages 56 and 57.
[d]Serious injuries are injuries that (1) require hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) result in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) cause severe hemorrhages or nerve, muscle, or tendon damage; (4) involve any internal organ; or (5) involve second- or third-degree burns, or any burn affecting more than 5% of the body surface.
[e]All NTSB actions are proposed requirements for the International Maritime Organization.

Event (NTSB02) Description: On February 9, 1991, the U.S. LASH ship STONEWALL JACKSON was underway in the Indian Ocean enroute from Singapore to the Suez Canal. At approximately 1423, an engineroom fire erupted when oil sprayed upward from the duplex lubricating oil strainer on the steam turbogenerator while the engineers were attempting to clean and change the strainer elements. In this accident, oil sprayed upward from the strainer and was ignited when it came into contact with the hot steam piping or surfaces of the turbine casing. All six of the on-duty engineering personnel lost their lives and about $2 million in damages resulted from this accident. (Description extracted from page 36 of the NTSB/MAR-95/04 report.[f])

[f]National Transportation Safety Board, *Marine Accident Report – Engineroom Fire On Board the Liberian Tankship SEAL ISLAND While Moored at the Amerada Hess Oil Terminal in St. Croix, U.S. Virgin Islands, October 8, 1994*, NTSB/MAR-95/04, December 1995.



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Event Number: NTSB02	Event Characterization	
	As Documented in the Event Report	**As Inferred from the Event Report**
System/Location	Lube oil/engine room	
Cause	Oil sprayed upward from the duplex lubricating oil strainer while the engineers were attempting to clean and change the strainer elements. (Specific cause of the spray is not provided in NTSB/MAR-95/04)	
Ignition Source	Hot surface (steam piping and/or turbine casing)	
Detection		Crew
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Not inferred
Impact on Propulsion	Not stated	Not inferred
Impact on Steering	Not stated	Not inferred
Human Casualty	Six fatalities	
Corrective Action to Prevent Recurrence[g]	Emergency escape breathing apparatus should be provided in engine rooms or other vessel spaces where personnel normally would be working and could be trapped by smoke or noxious fumes Owners of other ships equipped with the same duplex strainer as was in use on the STONEWALL JACKSON should install spray shields around them to prevent oil from spraying on hot piping or turbine surfaces	

[g]Recommendations by the U.S. Coast Guard investigating officer.

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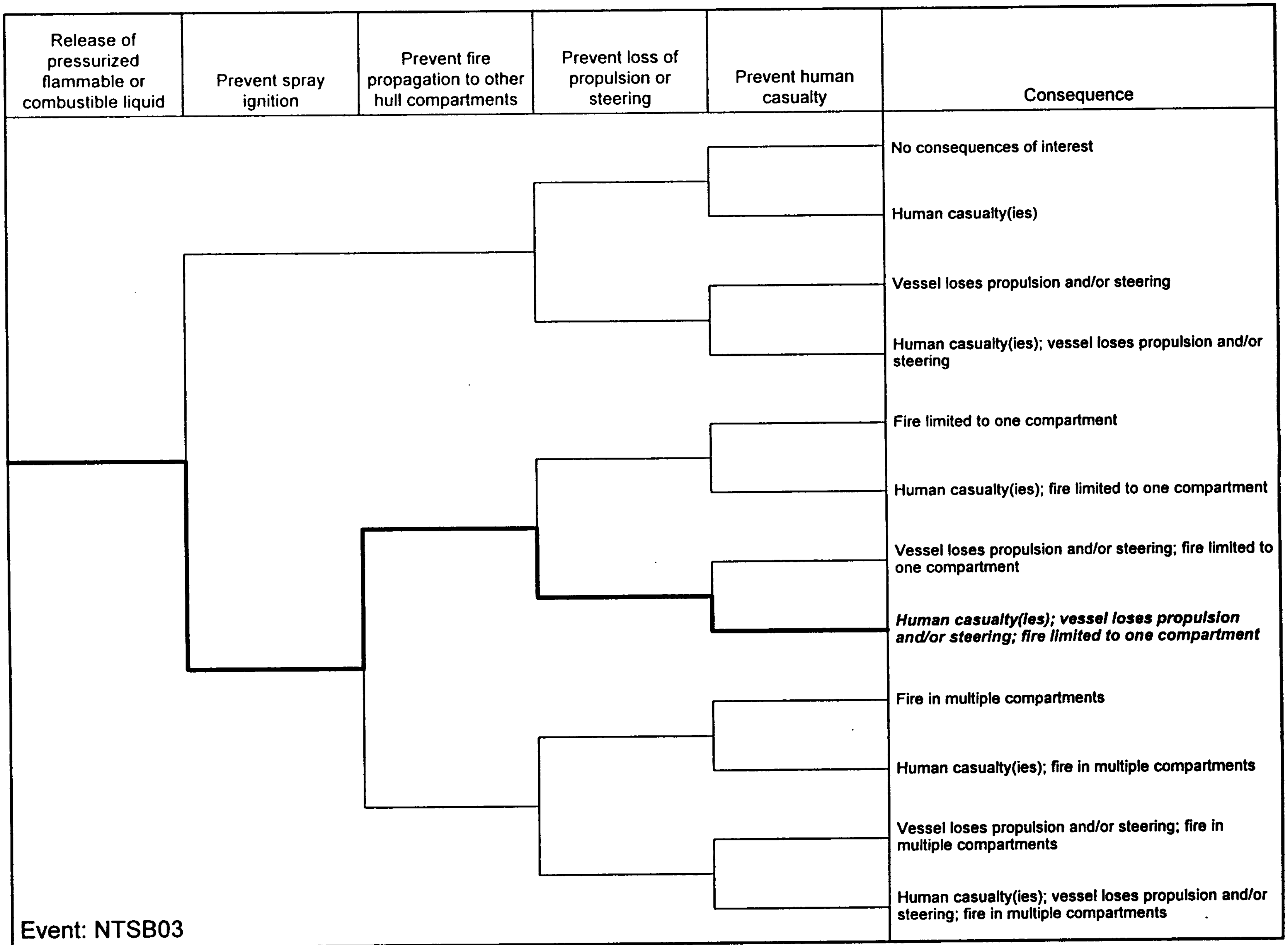
Event (NTSB03) Description: On December 22, 1981, the Massachusetts Maritime Academy training ship BAY STATE was moored at the academy at Buzzard's Bay, Massachusetts. Shortly after 1230, an on-watch engineering cadet and a second class cadet engineer were behind the ship's starboard boiler, attempting to shift strainers in the high pressure boiler fuel oil duplex strainer. Both cadets had difficulty moving the strainer's directional flow valve handle. Finally, the cadet engineer kicked at the lever with his foot. He stated that his foot slipped, then struck and broke off the brass vent cock valve from the cover of the forward strainer basket, which was in service. A pressurized (300 psi) spray of heated (150°F) fuel oil shot up over 12 feet, contacting a steam pipe line, and ignited. One fatality and 2 serious injuries resulted; the vessel's engineroom was destroyed and the vessel was scrapped. (Description extracted from page 36 of the NTSB/MAR-95/04 report.[h])

[h]National Transportation Safety Board, *Marine Accident Report – Engineroom Fire On Board the Liberian Tankship SEAL ISLAND While Moored at the Amerada Hess Oil Terminal in St. Croix, U.S. Virgin Islands, October 8, 1994*, NTSB/MAR-95/04, December 1995.



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Event Number: NTSB03	Event Characterization	
	As Documented in the Event Report	As Inferred from the Event Report
System/Location	Fuel oil/engine room	
Cause	While attempting to move a strainer's directional flow valve handle, a cadet engineer kicked at the lever with his foot. His foot slipped, striking and breaking off a brass vent cock valve from the cover of the forward strainer basket, which was in service	
Ignition Source	Hot surface (steam pipe line)	
Detection	Crew	
Release Isolation	Not stated	Not inferred
Fire Suppression	Not stated	Unsuccessful (the engine room was destroyed)
Impact on Propulsion		Loss of propulsion (the engine room was destroyed)
Impact on Steering		None
Human Casualty	One fatality and two serious injuries	
Corrective Action to Prevent Recurrence	Install spray shields around flammable liquid strainers[i] Conduct training drills to acquaint all persons on board the training ship with the various routes available to exit the engine room[j]	

[i]Recommendations by the NTSB to the U.S. Maritime Administration (the vessel's owner).
[j]Recommendations by the NTSB to the Massachusetts Maritime Academy.

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APPENDIX H

Preliminary Recommendations

Preliminary Recommendation 1: *Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil (i.e., monolithic equipment housing that integrates fuel oil/lube oil piping, particularly the discharging piping)*[a]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Failure of tie-in piping has caused several fires in engine rooms. Eliminating/reducing tie-in piping, including associated flanges, valves, etc., should help reduce the frequency of these fires	This recommendation would reduce the piping that is under the control of the manufacturer (i.e., the piping that comes with the engine skid or pump skid). However, it does not affect piping outside the engine skid (e.g., piping from the oil tanks to strainers and filters, and piping from strainers and filters to the engine) This type of engine may still require gauges (e.g., temperature, pressure) and associated lines to the engine's passage ways. These instruments and instrument lines are still susceptible to failure caused by equipment failure or human error. That is, tie-in piping can be reduced but not necessarily eliminated	This recommendation is generally not feasible for existing ships (i.e., it is not feasible to replace all existing engines and pumps with new equipment) These types of engines and pumps may not be available for all applications. For example, these engines and pumps may not be available for all engine and pump sizes. Also, they may not operate efficiently and reliably for all types of fuel oil or lube oil, and they may require excessive maintenance in some applications The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 35% reduction in the frequency of spray fires*

[a]*Engine Room Fire – Guidance to Fire Prevention*, page 41, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

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Preliminary Recommendation 2: *Sheath, cover, or provide deflector shield for fuel/lube oil piping, tubing, and hoses (particularly fittings, flanges, and flexible joints) in high pressure service and/or that are attached to diesel engines, pumps, turbochargers, boilers, or oil tanks. Deflector shields should also be provided for equipment flanges such as the cover flanges on strainers, filters, coalescers, and purifiers used in fuel/lube oil systems. In the case of fuel oil injection tubing for diesel engines, tubing should be fastened on both sides to prevent movement in case of catastrophic failure, and a deflector shield should be provided on each side to help divert sprays away from hot surfaces (e.g., exhaust manifold and pipe)*[a]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Sheath, cover, and deflector shield may prevent leaks in high-pressure systems from spraying into the surrounding areas. Specific ways of implementing this recommendation include providing secondary pipe or hose (e.g., for fuel oil lines on large diesel engines), spray-preventing tape, insulation/lagging, and flange deflector shield	Sheathing often needs to be removed before performing equipment maintenance, which makes it ineffective during maintenance (several fires occurred when the crew was performing maintenance on the equipment) It may not be possible to sheath all fuel oil/lube oil piping, tubing, and fittings. For example, it may be difficult to sheath the lube oil piping to turbochargers. Also, at least for some engine types and sizes, it may be difficult to sheath the nozzles and fittings on either side of the engine injection tubing	Maintenance personnel may fail to reinstall sheathing after maintenance or may reinstall it incorrectly. (Sheathing can be useful in helping prevent fires, but it requires strict control to be effective) Spray-preventing tape is easier to install than flange shield, and it requires less training for proper installation. However, tapes are not reusable after removal for maintenance The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 29% reduction in the frequency of spray fires and 26% reduction in the frequency of fires involving injury or fatality*

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Preliminary Recommendation 3: *Sheath hot surfaces (e.g., engine exhaust manifold or pipe, turbine casing, turbocharger casing, steam line) in the vicinity of fuel/lube oil systems.*[a] *Also, review existing design specifications and installation guidelines for insulation/lagging to ensure that these specifications and guidelines include provisions for preventing ignition (e.g., oil-repellant paint, positioning of seams away from potential sources of spray, covering of any openings in the insulation/lagging for instrument and valve line)*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Hot surface is by far the most common source of ignition of sprays of fuel/lube oil in engine rooms. Sheathing these surfaces should help prevent contact of fuel/lube oil with hot surfaces, thereby reducing the probability of ignition	Sheathing is typically provided to help (1) protect personnel from burn hazards and (2) reduce the heat load on ventilation systems. Therefore, it will not necessarily cover all hot surfaces that could be sources of ignition. For example, there may be openings in the insulation/lagging for instrumentation and vent/drain valves. An oil spray could infiltrate through these openings and ignite. As another example, sheathing is not required for personnel protection if the hot surface is out of reach for personnel. Also, insulation is typically provided for steam piping and steam turbine casing, but it may not be provided for the pipe hangers	Maintenance personnel sometimes fail to reinstall sheathing after maintenance. (Sheathing can be useful in helping prevent fires, but it requires strict control to be effective) To achieve maximum benefits, all hot surfaces near potential sources of oil sprays (e.g., strainers) in the engine room should be insulated. It may be necessary to measure the temperature on potential hot surfaces (e.g., steam pipe hangers) to determine whether sheathing is necessary The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 38% reduction in the frequency of fatal incidents from spray fires*

Preliminary Recommendation 3 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
	In addition, current design specifications and installation guidelines for insulation/lagging have been developed for personnel protection and control of heat load. Therefore, they may not address issues related to preventing ignition of oil sprays. For example, while some types of lagging paint are not oil repellant and may allow soaking of insulation from oil sprays, there appear to be no specifications/guidelines for selecting paint that is oil repellant	

Preliminary Recommendation 4: *Provide deflector shielding (e.g., metal plate) between fuel oil/lube oil strainer, filter, coalescer, or purifier (which can be sources of high-pressure fuel/lube oil sprays) and potential sources of ignition (e.g., engine exhaust manifold or pipe, turbine casing, turbocharger casing, steam line). Shielding should be installed in such a way that it does not have to be removed for performing equipment maintenance, which would make shielding ineffective during maintenance (several fires occurred when the crew was performing maintenance on the equipment)* [b, c, d, e]		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
Hot surfaces are by far the most common source of ignition of sprays of combustible liquids in engine rooms. Providing deflector shielding between the potential sources of sprays and the potential sources of ignition should help prevent direct contact of sprays with the most common source of ignition. This should help reduce the probability of ignition	Some conceptual shielding designs consist of a metal "box" that encapsulates the strainers, filters, etc. The box has a top, three closed walls, and one open side (with or without a cover). The open side allows for equipment maintenance. However, these designs may direct sprays that occur during maintenance onto the crew member performing this activity	Maintenance personnel sometimes fail to reinstall shielding after maintenance. (Shielding can be useful in helping prevent fires, but it requires strict control to be effective)

[b]National Transportation Safety Board (NTSB), *Marine Accident Report – Engineroom Fire On Board the Liberian Tankship SEAL ISLAND While Moored at the Amerada Hess Oil Terminal in St. Croix, U.S. Virgin Islands, October 8, 1994*, NTSB/MAR-95/04, December 1995.

[c]Recommendation by the U.S. Coast Guard investigating officer regarding the fire on board the U.S. LASH ship STONEWALL JACKSON, as described in NTSB/MAR-95/04.

[d]Recommendation by the NTSB to the U.S. Maritime Administration (the vessel's owner) regarding the fire on board the Massachusetts Maritime Academy training ship BAY STATE, as described in NTSB/MAR-95/04.

[e]*Engine Room Fire – Guidance to Fire Prevention*, page 65, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

Preliminary Recommendation 4 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 50% reduction in the frequency of fatal incidents from spray fires*

Preliminary Recommendation 5: *Use water instead of oil to provide cooling to fuel oil injector valves*[f]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents several engine room fires involving generator engines. A common cause of these fires has been the breakage of the cooling oil pipe for fuel oil injection valves (NK11 through NK14 in Attachment D). Using cooling water instead of cooling oil for the fuel oil injector valve should help prevent these fires However, this type of incident (spray of cooling oil) has not been documented in other databases (i.e., other than the NK report), and it does not appear to be a worldwide problem. In fact, there were no injuries or fatalities that resulted from sprays of cooling oil		The hazard analysis team does not consider this preliminary recommendation a feasible, practical method to reduce risks. *The impact of implementing this recommendation is minimal (about 3%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

[f] *Engine Room Fire – Guidance to Fire Prevention*, page 42, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994. Note: This recommendation from the NK report is somewhat unclear about the "fuel oil valves." We *assumed* that the "fuel oil valves" in this NK recommendation are the fuel oil injection valves used in large diesel engines.

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Preliminary Recommendation 6: *Position flexible joints in boiler fuel oil supply systems so that they are less susceptible to secondary damage due to furnace explosions*[8]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents five engine room fires (NK17 through NK21 in Attachment D) involving failure of flexible joints in the boiler fuel oil supply system. In all five cases, the NK report indicated that flexible joints failed due to secondary damage from a furnace explosion. The NK report suggested that positioning the flexible joints so that they are less susceptible to secondary damage due to furnace explosions should help reduce these fires	The NK report provides no specific suggestions about the repositioning of flexible joints. In fact, the hazard analysis team could not identify feasible, practical methods for implementing this recommendation. (More practical methods may include providing explosion relief panels, which could divert the impact away from the joints, or providing physical barriers [shielding] for the joints)	The hazard analysis team does not consider this preliminary recommendation a feasible, practical method to reduce risks. *The impact of implementing this recommendation is insignificant in reducing the frequency of spray fires and the frequency of injury/fatality from spray fires*

[8] *Engine Room Fire – Guidance to Fire Prevention*, page 43, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

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Preliminary Recommendation 7: *Use flexible joints for the burners of the top firing boiler and fuel oil (boiler supply and pilot) piping*[8]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report discussed an engine room fire (NK22 in Attachment D) involving failure of a union fitting in the diesel oil supply piping. This fitting failed because of vibration. The NK report suggests that flexible joints are less susceptible to failure from vibration However, this type of incident has not been documented in other databases (i.e., other than the NK report), and it does not appear to be a worldwide problem. (This may be because most burners on ships worldwide already have flexible joints.) In fact, there were no injuries or fatalities that resulted from this type of incident		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. *The impact of implementing this recommendation is minimal (less than 1%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

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Preliminary Recommendation 8: *Do not use sight glasses to monitor level in fuel oil tanks*[h]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents an engine room fire (NK23 in Attachment D) that was caused by breakage of a glass level gauge in the fuel oil tank. Because they are more fragile than other parts of the fuel oil system (e.g., piping), sight glasses may be more susceptible to breakage by external impact However, this type of incident has not been documented in other databases (i.e., other than the NK report), and it does not appear to be a worldwide problem. In fact, there were no injuries or fatalities that resulted from this type of incident		The hazard analysis team agrees that standard sight glasses may be susceptible to breakage by external impact. However, there are robust sight glass designs (e.g., protected with guards) that have been widely used and are acceptable to the Coast Guard. In fact, fuel-oil sight glasses used on U.S.-flag vessels must have guards (as well as ball check valves). Therefore, the hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. *The impact of implementing this recommendation is minimal (less than 1%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

[h]*Engine Room Fire – Guidance to Fire Prevention*, page 44, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

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Preliminary Recommendation 9: *Ensure that air vent pipes connected to fuel/lube oil tanks are not open to the engine room*[h]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents several engine room fires (e.g., NK24, NK25, and NK36 in Attachment D) that resulted from overflows of fuel/lube oil from tanks		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. This is primarily because it is already required by some administrations (e.g., U.S.-flag ships) and by some classification societies (e.g., American Bureau of Shipping) for air vents on fuel oil tanks. *The impact of implementing this recommendation is minimal (less than 3%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

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Preliminary Recommendation 10: *Combustible oil tanks shall not be installed above equipment with high temperature surfaces such as engine, boiler, and waste oil incinerator*[h]		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
This recommendation may apply mostly to lube oil tanks, which are often located close to and/or above high temperature surfaces. An alternative may be to require that pans and drains be provided to drain spills away from the hot surface. However, our review of the incidents in Attachments A through G indicated that the location of oil tanks is rarely a contributing factor in spray fires		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. *The impact of implementing this recommendation is minimal (less than 1%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

[Blank]

Preliminary Recommendation 11: *Steam blowing pipes shall not be installed in the flammable oil tank. If installation of these pipes is unavoidable, then a valve locking device shall be installed to prevent inadvertent operation*[h]		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
The hazard analysis team did not understand this recommendation. "Steam blowing pipes" may refer to steam heating coils or some other steam pipe that goes through an oil tank (e.g., surface blowdown line). However, our review of the incidents in Attachments A through G indicated that this was not a contributing factor in spray fires		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. *The impact of implementing this recommendation is insignificant in reducing the frequency of spray fires and in reducing the frequency of injury/fatality from spray fires*

[Blank]

Preliminary Recommendation 12: *The short sounding pipe of a double bottom fuel oil tank must be located at a safe distance from potential sources of ignition. Alternatively, appropriate spray shield may be used*[i]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents three fires (NK26, NK27, and NK39 in Attachment D) that occurred during replenishment of fuel in a double bottom fuel tank. They resulted from fuel gushing out of the sounding pipe of the tank in the engine room and coming into contact with a source of ignition (usually hot surface). However, we found no similar incidents in most of the other databases		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks (primarily because these pipes are typically located away from potential sources of ignition, and Coast Guard inspectors already pay attention to sounding pipe hazards). *The impact of implementing this recommendation is minimal (less than 3%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*

[i]*Engine Room Fire – Guidance to Fire Prevention*, page 58, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

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Preliminary Recommendation 13: *Use short sounding pipe device that retains air tightness even during measurements. Alternatively, use level gauges instead of conventional sounding methods*[i]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report documents three fires (NK26, NK27, and NK39 in Attachment D) that occurred during replenishment of fuel in a double bottom fuel tank. They resulted from fuel gushing out of the sounding pipe of the tank in the engine room and coming into contact with a source of ignition (usually a hot surface) According to the NK report, the current design of self-closing devices is such that crew members have a tendency to disable the self-closing mechanism. Specifically, the crew has to make frequent sounding measurements during replenishment, and crew members often keep sounding tape in the sounding pipe. This prevents the self-closing device from closing		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. *The impact of implementing this recommendation is minimal (less than 4%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires*. In addition, devices that retain air tightness may be prohibitively expensive for this application. (These devices are widely used for "closed gauging" of hazardous chemical tanks, but the hazard analysis team members are not aware of usage on fuel/lube oil tanks)

[Blank]

Preliminary Recommendation 14: *Duplex devices such as strainers, filters, or coalescers should not be opened when the fuel/lube oil system is in operation and pressurized. This can be accomplished administratively (i.e., never allow opening the devices when the oil system is pressurized). On new installations, parallel simplex devices (with double-blocking shutoff and bleed valve arrangements) or, when commercially available, self-cleaning (e.g., backwash type) devices can be used*[c]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Among the oil fires documented in Attachments A through G, duplex strainers, filters, or coalescers have been involved in about 13% of all fires, 25% of the fires with injury or fatality, *and 50% of fires with fatality*	Self-cleaning devices (e.g., strainers) are common for lube oil applications on large diesel engines, but they may not be available for small-engine applications and for fuel oil applications	The hazard analysis team considers this preliminary recommendation the second most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 50% reduction in the frequency of fatal incidents from spray fires*

[Blank]

Preliminary Recommendation 15: *Ensure that safety and reliability information is developed and maintained for all systems containing pressurized fuel/lube oil*[j]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
This information includes the hazards (e.g., fire) posed by these systems and system/mechanical design information. This information includes materials of construction, system diagrams, equipment and piping specifications, descriptions of emergency shutdown systems, and descriptions of fire protection systems. For example, for U.S.-flag ships, the Coast Guard requires ships to have drawings of the fuel oil transfer system (posted along with fire and safety information), and changes to these drawings must be approved by the Coast Guard. The Coast Guard also requires information about fire protection and emergency shutdown systems		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. This is primarily because most information considered critical for the risks considered in this study is already available from the manuals provided by the equipment manufacturers (e.g., diesel engine replacement parts are specified in the manufacturer's manual), or from fire protection/emergency planning requirements from administrations (e.g., Coast Guard) or classification societies. We found no instances (in the incidents documented in Attachments A through G) in which "lack of information" was a significant contributing factor to the incident. *The impact of implementing this recommendation is insignificant in reducing the frequency of spray fires and in reducing the frequency of injury/fatality from spray fires*

[j]Adapted from American Petroleum Institute (API) Recommended Practice 75, *Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities*, API, Washington, DC, May 1993. This recommendation also appears in management practices, standards, and codes applicable to facilities that process, store, or otherwise handle highly hazardous materials:

-*The Process Safety Code of Management Practices*, Chemical Manufacturers Association (CMA), Washington, DC, 1990.
-API Recommended Practice 750, *Management of Process Hazards*, API, Washington, DC, 1990.
-Occupational Safety and Health Administration (OSHA), *Process Safety Management of Highly Hazardous Chemicals*, 29 CFR 1910.119.

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Preliminary Recommendation 16: *Ensure that hazard analyses are performed for systems containing pressurized fuel oil or lube oil. The hazard analyses should consider human factors, previous incidents, and equipment location issues. These should also address all phases of operation (startup, shutdown, maintenance, temporary operations, etc.)*[j]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The objective of these hazard analyses should be to minimize the likelihood of the occurrence of spray incidents, and this is accomplished by systematically identifying and evaluating all equipment/systems that contain pressurized fuel/lube oil[k] Special consideration should be given to human factors, previous incidents, and equipment location issues, and hazard analyses should consider all phases of operation (startup, shutdown, maintenance, temporary operations, etc.)		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. This is primarily because many of the causes and contributing factors to spray fires are typical of hazards considered in a hazard analysis. Thus, several of these incidents might have been avoided if periodic hazard analyses had been performed on these ships. *The expected impact of implementing this recommendation is about 26% reduction in the frequency of fatal incidents from spray fires*

[k]*Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples*, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 1992.

Preliminary Recommendation 16 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Industry regulations and standards generally request initial hazard analyses and periodic reviews and updates. Also, regulations and standards request that 1. the hazard analysis be performed by a team knowledgeable in engineering, operations, design, safety, environmental, and other specialties (e.g., fire protection), as appropriate, and 2. at least one member of the hazard analysis team should be proficient in the hazard analysis methodologies used		

Preliminary Recommendation 17: *Ensure that all alterations (i.e., modifications that are not replacements in kind [RIKs])[l] to high-pressure fuel/lube oil systems are unambiguously posted/logged for the other chief engineers and for the company records. These alterations should be reviewed by the company (e.g., at arrival in the next port) and during inspections by administrations (e.g., Coast Guard) and classifications societies[j,m]*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
This preliminary recommendation was originally a recommendation for developing and implementing a complete management of change (MOC) system for all high-pressure fuel/lube oil systems as well as related safety systems and equipment (e.g., fire protection). However, several of the elements of an MOC system already exist in most engine rooms. Thus, we changed the original recommendation to emphasize the one element (documenting alterations to fuel/lube oil systems) of an MOC system that we believe is not currently common practice in the shipping industry	Many repairs of fuel oil and lube oil systems result from failures that occur while the ship is underway. Crew members often have to improvise if spare parts and equipment are not available. Documentation of alterations should improve the chances that unsafe conditions introduced by the alteration will be detected and corrected. However, detection and correction may take some time (e.g., when the ship reaches the next port)	The hazard analysis team considers this preliminary recommendation useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 7% reduction in the frequency of fatal incidents from spray fires*

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[l]RIK is an item (equipment, procedure, etc.) that meets the design specification of the item it is replacing. This can be an identical replacement or any other design alternative specifically provided for in the design specification, as long as the alternative does not in any way adversely affect the use of the item or associated items.

[m]*Engine Room Fire – Guidance to Fire Prevention*, page 42, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994 (recommends providing a means to ensure that nonapproved parts [e.g., pipe, gasket] will not be used in fuel oil and lube oil systems).

Preliminary Recommendation 17 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Ships sometimes undergo changes (e.g., to increase efficiency and accommodate technical innovation). Also, on occasion, temporary repairs, connections, bypasses, or other modifications may be made out of necessity. Any of these changes can introduce new hazards or compromise the safeguards built into the original design For example, a fire on board the SEAL ISLAND (Event NTSB01 in Attachment G) resulted in the death of three crew members and serious injury to six other crew members. The NTSB determined that the probable cause of the fire on board the SEAL ISLAND was the chief engineer's failure to recognize the risks introduced by a *temporary repair* to the engine room oil strainer	Unfortunately, in some cases, the unsafe conditions cause failures shortly after the repair is performed. Incident NK04 is a good example of an incorrect repair causing a fatal incident shortly after the repair was completed. The effectiveness of this recommendation is reduced in this case	

Preliminary Recommendation 17 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
As another fatal example, the NK report documents an incident (Event NK04 in Attachment D) that involved a crew member replacing a steel portion of a fuel oil mixing column pipe work with a pipe made of plastic. The plastic pipe ruptured during operation, resulting in a fire that killed one crew member. Preventing the use of nonapproved parts in fuel oil and lube oil systems should reduce the frequency of these types of accidents An MOC system identifies and controls hazards associated with changes and maintains the accuracy of safety and reliability information.[n] Examples of changes that should be considered for inclusion in the scope of MOC systems include changes to: 1. system/equipment (e.g, using a different type of gasket in a fuel oil system) 2. operating, inspection, or maintenance procedures 3. safe work practices 4. safety-related systems (e.g., fire protection)		

[n]M. L. Casada et. al., *A Manager's Guide to Implementing and Improving Management of Change Systems*, CMA, Washington, DC, September 1993.

Preliminary Recommendation 17 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
5. personnel (e.g., reducing the number of crew members), and 6. organization (e.g., switching from separate maintenance organizations that support selected types of ships for one company to a centralized maintenance organization that supports all ships for the company)		

Preliminary Recommendation 18: *Ensure that standard operating procedures (SOPs) are developed and implemented to (1) operate duplex strainers/filters/coalescers in high-pressure fuel/lube oil systems (SOPs should be posted at the device location), (2) operate (startup, shutdown, etc.) propulsion and auxiliary boilers, and (3) fill fuel/lube oil tanks in machinery spaces. SOPs should include all phases of operation, the hazards associated with the procedure, and the personal protective equipment that should be used*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
This preliminary recommendation was originally a recommendation for developing and implementing a complete set of SOPs to operate, inspect, and maintain all systems containing pressurized fuel/lube oil as well as related safety systems and equipment (e.g., fire protection). However, some of the SOPs and manuals required for safe operation of oil systems and related systems already exist in engine rooms. Thus, we changed the original recommendation to emphasize the SOPs that may not be currently widely available and used in the shipping industry	There are often difficulties with language. For example, an engine room crew may be composed of Italian nationals and Philippine nationals. Crew members would use their native language to communicate among themselves and English as the common language for communication between the different nationalities. Some of the manuals on board could be in German if the equipment was made in Germany	The hazard analysis team considers this preliminary recommendation useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 7% reduction in the frequency of fatal incidents from spray fires*

Preliminary Recommendation 18 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
It is widely recognized that a set of SOPs can help reduce the likelihood of human errors.[o] Providing these SOPs on board ships is crucial because personnel errors are significant contributors to the risk associated with pressurized oil systems. In fact, several engine room fires resulted from personnel errors during operation of fuel oil/lube oil equipment (e.g., replacing strainer elements). To reduce the frequency of these types of incidents, the NK report recommended written, step-by-step procedures for operating strainers and purifiers.[c] (The procedures should be available at the location of the equipment)		

[o]D. K. Lorenzo, *A Manager's Guide to Reducing Human Errors – Improving Human Performance in the Chemical Industry*, CMA, Washington, DC, July 1990.

Preliminary Recommendation 18 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The NK report also documents several engine room fires (NK17 through NK21 in Attachment D) that were initiated by malfunction of the boiler burner. These malfunctions resulted in explosion, damage to expansion joints in the fuel oil system, and subsequent fire. The NK report suggested that the frequency of occurrence of these explosions can be reduced by providing adequate purging of the furnace before startup.[8] One way to help ensure adequate purging is to write (and enforce) the steps, including purging, required for safe startup of the furnace		

Preliminary Recommendation 18 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Another fire (NK27 in Attachment D) occurred during replenishment of fuel in a double bottom fuel tank. After replenishment, the oil remaining in the piping system was purged with air, but the air space in the tank was insufficient for the purging operation because the tank was overfilled. (Also, there is a high probability of fuel oil overflowing due to changes in trim and heel, sea conditions, and changes in temperature) To prevent this type of incident, the NK report suggests procedural controls (i.e., fuel oil tanks should not be filled above 90% to 95% of the tank's capacity).[i] Again, one way to help ensure adherence to procedural steps is to write the steps required for safe operation, including safe operation limits (e.g., maximum tank level)		

Preliminary Recommendation 18 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
As a last example of the importance of adequate procedures, the Australian Marine Incident Investigation Unit (MIIU) investigated the fire on board the fishing vessel NORTHERN L (MIIU03). MIIU concluded that the "quality of the operational procedures and standards practiced (or not practiced) aboard the NORTHERN L created the conditions in which accidents were more likely to occur, and where emergencies were more likely to get out of hand" The different types or procedures that should be documented include inspection, test (e.g., for standby systems), and maintenance. They should consider: 1. all phases of operation (e.g., startup, normal, shutdown, temporary, emergency) 2. the hazards associated with the procedure 3. the safe operating limits (e.g., maximum oil tank inventory) 4. personal protective equipment (PPE) required 5. the consequences of deviating from the procedural steps (skipping or performing incorrectly), and 6. actions required to correct or avoid deviations		

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Preliminary Recommendation 19: *Establish and implement safe work practices for fuel/lube oil systems (particularly duplex devices such as strainers, filters, and coalescers), including safety policies for (1) wearing personal protective equipment and ensuring availability of breathing apparatuses and fire protection equipment, (2) isolating equipment for inspection and maintenance (e.g., replacing elements in duplex strainers), (3) verifying that the equipment is depressurized, including labels and warning signs posted at the equipment location, (4) providing means (e.g., vents, bleeders, gauges) to verify depressurization of equipment that is isolated for inspection/maintenance, (5) ensuring that all vent/bleeder valves for fuel/lube oil equipment are self-closing valves and that these valves are plugged or capped when not in use, and (6) ensuring that the discharge of all vent and bleed valves are routed to a safe location*[j]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
MSIS22 in Attachment B describes a fatal incident that resulted from following unsafe practices in preparation of a vessel for the winter (crew member was using a handheld torch to warm up and unplug an oil transfer line). Other fires resulted from inadequate preparation of the equipment for maintenance (i.e., release of pressurized liquid when the equipment is opened for maintenance). In some instances, no means (pressure gauge, vent/bleed valve, etc.) were available to allow the crew to verify that the equipment was depressurized and properly isolated for maintenance	Regarding verification that equipment (e.g., strainer) is depressurized, some instruments may not work properly in some services. For example, a pressure gauge can plug in dirty-oil service	Providing the means to verify that the equipment is depressurized does not ensure that the crew will perform this verification. This recommendation requires adequate training of personnel and strict controls to ensure that personnel follow established procedures

Preliminary Recommendation 19 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
In fact, the NK report recommends that means should be provided to verify that high pressure equipment, particularly fuel oil and lube oil strainers, are depressurized before opening the equipment for maintenance[p, q]		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 27% reduction in the frequency of fatal incidents from spray fires*

[p] *Engine Room Fire – Guidance to Fire Prevention*, page 42, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

[q] *Engine Room Fire – Guidance to Fire Prevention*, page 64, Nippon Kaiji Kyokai (NK), Tokyo, Japan, September 1994.

Preliminary Recommendation 20: *Supplement periodic training of engine room personnel with a short video on the hazards of fuel/lube oil systems, including (1) synopses of some of the most catastrophic incidents (e.g., SEAL ISLAND), (2) typical causes, equipment involved, ignition sources, and consequences of spray fires, and (3) the relatively high risk of lube oil compared to fuel oil*[b]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Several fires in the engine room resulted from human errors during operation and/or maintenance of equipment (e.g., strainer). It is clear in many cases that the crew did not know how to safely perform the activity. Also, it is clear that they did not fully understand the hazards associated with operating/maintaining the equipment. This is particularly true for the operation of fuel oil and/or lube oil strainers (i.e., replacement of the strainer element). In fact, the NK report recommended providing training for operating and maintaining strainers and purifiers[e]		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 43% reduction in the frequency of fatal incidents from spray fires*

Preliminary Recommendation 20 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Additionally, improved training is the most common "corrective action" listed for the incidents in Attachment A. (Attachment A contains the MISREP reports, which are usually more complete [compared to the reports in the other attachments] regarding corrective actions to prevent recurrence.) This indicates that there may be significant deficiencies in training programs for many ships. The crew must be trained to work safely, including specific training in the written procedures, safe work practices, and emergency response and control measures Industry regulations and standards generally request initial training, periodic (refresher) training, and training certification programs. Additionally, industry regulations and standards request that whenever a change is made, all affected personnel should be trained or otherwise informed of the change before implementing the change		

Preliminary Recommendation 21: *Ensure that the inspection and maintenance programs for fuel/lube oil equipment includes (1) demonstration of the operation of three-way transfer valves in duplex strainers/filters/coalescers (these valves must move easily for one person without the need for impact [as from a hammer or a foot] or leveraging [as with a length of pipe or other temporary extension of the valve handle]), (2) periodic inspection and replacement of tubings and fittings on diesel engines and turbochargers, and (3) provisions for periodic inspection of devices that prevent sprays of oil (covers, deflector shields, tapes, plugs/caps for vent and drain valves, etc.) and devices that prevent oil sprays from contacting hot surfaces (insulation, lagging, etc.), including ensuring that these protections are re-installed whenever they need to be removed for maintenance*[g, h, j, p]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
This preliminary recommendation was originally a recommendation for developing and implementing a program for ensuring quality and mechanical integrity of fuel/lube oil systems and related safety systems and equipment (e.g., fire protection, PPE). However, many elements of quality and mechanical integrity programs are already in place in the shipping industry. Thus, we changed the original recommendation to emphasize deficiencies that exist (as indicated by the incidents in Attachments A through G) in the shipping industry		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 24% reduction in the frequency of fatal incidents from spray fires*

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Preliminary Recommendation 22: *Ensure that a pre-startup safety review (PSSR) program is developed and implemented for all systems containing pressurized fuel/lube oil*[j]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
PSSRs cover new or significantly modified systems to confirm that (1) construction and equipment are in accordance with specifications, (2) all written procedures (operating, maintenance, emergency, etc.) are in place, (3) safety and reliability information is current, (4) a hazard analysis has been performed and all recommendations from the hazard analysis have been addressed, (5) training has been completed, and (6) safe work practices are in place		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. This is primarily because a significant portion of the requirements of a PSSR is already performed by classification societies (e.g., American Bureau of Shipping) or is covered in other recommendations in this attachment. *The impact of implementing this recommendation is insignificant in reducing the frequency of spray fires and the frequency of injury/fatality from spray fires*

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Preliminary Recommendation 23: *All ships should (1) provide readily accessible emergency breathing apparatus to facilitate escape from engine rooms and (2) conduct periodic engine room fire and evacuation drills. The International Maritime Organization (IMO) should develop a standard for engine room fire and escape drills*[j]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
This preliminary recommendation was originally a recommendation to ensure that an emergency response and control program is developed and implemented, including addressing emergencies involving systems containing pressurized fuel/lube oil. However, regulations and practices in the shipping industry require emergency action plans with assigned authority to the appropriate persons, evacuation procedures, and training/drills. Therefore, we modified this recommendation to focus on selected issues that may not be completely addressed in current practices and regulations		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 25% reduction in the frequency of fatal incidents from spray fires*

Preliminary Recommendation 23 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
Specifically, based on the incidents documented in Attachments A through G, it is evident that emergency action plans have been inadequate for emergencies initiated by or involving fuel/lube oil systems in the engine room. In fact, many incident investigation teams have identified deficiencies during fires on board vessels. For example, an NTSB incident investigation team proposed the following specific recommendations regarding the fire on board the SEAL ISLAND (some of these recommendations were also made regarding the fires on board the STONEWALL JACKSON and BAY STATE):[b] 1. All ships maintain readily accessible emergency breathing apparatus to facilitate escape from the engine room 2. Periodic engine room fire and escape drills		

Preliminary Recommendation 23 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
3. IMO should develop a standard for engine room fire and escape drills that will include, at a minimum, how to locate and don breathing apparatus and how to find and use emergency exits in simulated fire conditions 4. Test all modes of fire pump starting systems, including electric, hydraulic, and pneumatic, during fire and boat drills		

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Preliminary Recommendation 24: *Ensure that an incident investigation program (with emphasis on learning from the incident and preventing recurrence) is developed and implemented for all systems containing pressurized fuel/lube oil*[1]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Incidents that result or could result in serious safety or environmental consequences should be investigated. Incident investigation programs generally include (1) prompt initiation of the investigation (considering the necessity of securing the incident scene and protecting personnel), (2) an investigation team with personnel knowledgeable of the hazards and systems involved, investigation techniques, and other specialties (e.g., fire protection), as required, (3) identification of the nature of the incident, the contributing factors, and recommendations to prevent recurrence, and (4) a follow-up system to ensure that all recommendations are addressed		Many administrations (e.g., U.S., Canada, Australia) and classification societies (e.g., Lloyd's Register of Shipping, Nippon Kaiji Kyokai) already have safety incident reporting systems. In fact, these systems provided all the data in Attachments A through G, and the research documented in this letter report would not be possible without such systems.

Preliminary Recommendation 24 (cont'd)

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
An important point highlighted in regulations and industry standards is that the intent of the investigation should be to learn from the incident and help prevent similar incidents. However, our review of the incident reports in the attachment to this letter report indicated that in approximately 30% of all incident reports, the incident investigation team did not find (or did not document) the cause of the incident in sufficient detail to help prevent recurrence In these reports, the listed "cause" of the incident is the ***proximate cause***,[r] which only characterizes the condition that is readily identifiable as leading to the incident. For example, as presented in Section 3.2, each of the event characterizations on pages A-62, A-65, A-116, A-122, A-125, and A-131 in the attachment to this letter report lists the failure of a line, joint, fitting, or gasket as the cause of the incident, and the event on page A-71 lists "crankcase explosion" as the cause of an oil spray		However, current efforts can be improved. In fact, as evidenced by many of the figures in Section 3 of this report, information is often missing from many of the reports from these systems. (For example, Figure 3.2 in Section 3.1 shows that the source of ignition is not stated in almost 30% of the oil fires compiled in Attachments A through G. Indeed, the need for improvements in incident reporting systems has already been recognized.[s]

[r]H. M. Paula and G. W. Parry, *A Cause-Defense Approach to the Understanding and Analysis of Common Cause Failures*, NUREG/CR-5460 (SAND89-2368), U.S. Nuclear Regulatory Commission, Washington, DC, March 1990.

[s]"Development of a National Maritime Safety Incident Reporting System; Request for Written Material," *Federal Register*, Vol. 63, No. 68, April 9, 1998.

Preliminary Recommendation 24 (cont'd)		
Comments and Potential Benefits	**Potential Limitations**	**Comments About Implementation**
That is, a component (e.g., engine) or piece-part (e.g., gasket) is listed as the cause of the occurrence, and the reason(s) for the component or piece-part failure is not provided in these incident descriptions It is important to know why these components failed to be able to develop corrective actions. For example, if it is also determined that a gasket failed because the wrong type of gasket was purchased for the application, then it is possible to propose improvements to prevent recurrence The reason, or "root cause," of these events must be determined during the investigation. The ***root cause*** of the incident is defined as the most basic reason(s) why the equipment/piping failed, any of which would, if corrected, prevent recurrence.[1] Because some improvement(s) in management systems could have helped prevent most (or all) of the incidents of interest, the root cause of these incidents is generally the absence, neglect, or deficiencies of management system features		

[1]D. L. Gano, "Root Cause and How to Find It," *Nuclear News*, pp. 39-43, Vol. 30, No. 10, August 1987.

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Preliminary Recommendation 25: *Ensure that an audit program is developed and implemented for the safety and reliability management programs applicable to systems containing fuel/lube oil*[i]

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
All areas of hazard management presented in this attachment should be audited periodically to ensure effective performance. The objectives of the audit include determining that all management programs (1) are in place, (2) incorporate all requirements, and (3) are effective. Audits should include review of documentation, interviews of various levels (ship and onshore facilities), and ship inspections. The findings of the audit should be provided to the management personnel responsible for the program, and management should establish a system to determine and document the appropriate response to the findings and ensure satisfactory resolution		The hazard analysis team does not consider this preliminary recommendation useful in reducing spray-related risks. This is primarily because a significant portion of the requirements of audits is already performed by classification societies (e.g., American Bureau of Shipping). *The impact of implementing this recommendation is insignificant in reducing the frequency of spray fires and the frequency of injury/fatality from spray fires*

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Preliminary Recommendation 26: *Provide fine-water mist systems for local application on selected equipment areas in engine rooms, including diesel engine, turbocharger, and duplex strainer/filter/coalescer areas.*[u] *Both remote and local actuation capability should be provided, and the local actuator should be easy to operate (e.g., similar to the actuators for safety showers and eye washes)*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Most fatal incidents described in Attachments A through G happened very fast (typically within seconds), and crew members had little or no time to react. It is clear in several of these cases that a readily accessible mist system could have helped the crew to evacuate the engine room. Also, there are many other fires (with no fatalities) in which the crew detected the fire at a relatively early stage but were unable to control it with portable extinguishers. These fires expanded and caused significant damage. It appears that a mist system could have prevented these fires from turning into larger, more costly fires		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 53% reduction in the frequency of fatal incidents from spray fires*

[u] G. G. Back et al., *Full-Scale Water Mist Design Parameters Testing*, R&DC 21/97, Hughes Associates, Inc., Baltimore, MD, September 1997.

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Preliminary Recommendation 27: *Develop guidelines for fuel/lube oil fittings and nipples used in high-pressure marine applications. The guidelines should address fittings/nipples on engine-mounted equipment as well as on piping, strainers, and other equipment used in high-pressure fuel/lube oil systems*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
Among the oil fires documented in Attachments A through G, skid piping, tubing, and hoses mounted on engine/pump skids have been involved in about 38% of all fires and 44% of the fires with injury or fatality. Many of these events were the result of failures of fittings (e.g., a flare fitting) and nipples. It is often clear in the incident description that more robust fittings and nipples would have helped prevent the incident		The hazard analysis team considers this preliminary recommendation one of the most useful in reducing spray-related risks. *The expected impact of implementing this recommendation is about 18% reduction in the frequency of spray fires and 22% reduction in the frequency of fires involving injury or fatality*

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Preliminary Recommendation 28: *When instrument signals (e.g., pressure indication) from fuel/lube oil systems are sent to gauge boards (either a local board by the engine or a central board), pneumatic/electronic transducers should be used near the instrument tap to avoid lengthy runs of tubing or piping containing oil*

Comments and Potential Benefits	Potential Limitations	Comments About Implementation
The MSIS database describes an engine room fire (see MSIS24 in Attachment B) that resulted from an instrument line failure. (The line that failed had been replaced 2 days before the incident, and it failed because the crew used a plastic line instead of the original plastic-coated steel line) While other databases (i.e., other than MSIS) have not reported similar incidents, most of the databases have several incidents involving "line cracked" or "line failed." It is possible that some of these events were in fact lengthy instrument lines		This preliminary recommendation does not appear useful in reducing spray-related risks (primarily because so few incidents occurred involving lengthy instrument lines). In fact, the impact of implementing this recommendation is minimal (less than 1%) in reducing the frequency of spray fires and insignificant in reducing the frequency of injury/fatality from spray fires However, because of the uncertainty in several event descriptions, it is possible that several other incidents involving "line cracked" or "line failed" resulted from lengthy instrument lines. Thus, the hazard analysis team believes that this recommendation should be implemented

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APPENDIX I

Qualitative Analysis of Oil Spray Incidents

Incident Number	Ignition	Source of Ignition	Loss of Propulsion or Steering	Human Casualty	Equipment Involved	System Involved	Damage (Thousands of Dollars)
MISREP01	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	Not stated
MISREP02	Yes	Turbocharger Casing	No	None	Turbocharger	Lube	Not stated
MISREP03	Yes	Turbocharger Casing	Yes	None	Skid Piping, Tubing, or Hose	Lube	Not stated
MISREP04	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Governor	Lube	Not stated
MISREP06	Yes	Turbocharger Casing	Yes	None	Valve or Instrument	Fuel	Not stated
MISREP08	No	Not Applicable	Yes	Injury	Duplex Strainer, Filter, or Coalescer	Fuel	Not stated
MISREP09	No	Not Applicable	No	Injury	Duplex Strainer, Filter, or Coalescer	Fuel	Not stated
MISREP10	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	Not stated
MISREP11	No	Not Applicable	No	Injury	Not Stated	Fuel	Not stated
MISREP13	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	Not stated
MISREP14	Yes	Spark from Friction	No	None	Skid Piping, Tubing, or Hose	Fuel	Not stated
MISREP15	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Turbocharger	Lube	Not stated
MISREP16	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Turbocharger	Lube	0
MISREP17	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	Not stated
MISREP19	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	0
MISREP20	Yes	Turbocharger Casing	No	None	Skid Piping, Tubing, or Hose	Lube	0.36
MISREP21	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Lube	0
MISREP22	No	Not Applicable	Yes	None	Duplex Strainer, Filter, or Coalescer	Lube	0.047
MISREP23	No	Not Applicable	No	None	Engine	Lube	126.849
MISREP24	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Lube	Not stated
MISREP25	No	Not Applicable	No	None	Air Compressor	Lube	0
MISREP28	No	Not Applicable	No	None	Engine	Lube	60.315
MISREP29	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	0.02
MISREP30	No	Not Applicable	Yes	Injury	Valve or Instrument	Lube	0.5
MISREP31	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Fuel	0.1
MISREP32	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Fuel	0.05
MISREP33	Yes	Turbocharger Casing	No	None	Turbocharger	Lube	0.15
MISREP34	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	0.03
MISREP35	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Fuel	0.3
MISREP36	No	Not Applicable	No	Injury	Valve or Instrument	Lube	0
MISREP37	No	Not Applicable	No	Injury	Skid Piping, Tubing, or Hose	Fuel	2.507
MISREP38	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Lube	31.2
MISREP40	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Lube	0.125
MISREP41	No	Not Applicable	Yes	Injury	Skid Piping, Tubing, or Hose	Fuel	0
MISREP42	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	Injury	Engine	Fuel	1.972
MISREP43	Yes	Turbocharger Casing	Yes	None	Pump	Lube	0.625
MISREP44	No	Not Applicable	No	Injury	Valve or Instrument	Fuel	0

Incident Number	Ignition	Source of Ignition	Loss of Propulsion or Steering	Human Casualty	Equipment Involved	System Involved	Damage (Thousands of Dollars)
MISREP45	Yes	Turbine Casing	No	None	Engine	Lube	0.52
MISREP46	No	Not Applicable	No	Injury	Valve or Instrument	Fuel	0.213
MISREP47	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	0
MISREP48	No	Not Applicable	No	Injury	Valve or Instrument	Lube	0
MISREP49	No	Not Applicable	No	Injury	Duplex Strainer, Filter, or Coalescer	Lube	0.375
MISREP50	No	Not Applicable	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	0
MISREP51	No	Not Applicable	No	None	Valve or Instrument	Lube	61
MISREP52	No	Not Applicable	No	None	Skid Piping, Tubing, or Hose	Fuel	0
MISREP53	No	Not Applicable	No	Injury	Valve or Instrument	Lube	0
MISREP54	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Reduction Gear	Lube	0.08155
MISREP55	No	Not Applicable	Yes	None	Duplex Strainer, Filter, or Coalescer	Fuel	0
MSIS01	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	Injury	Skid Piping, Tubing, or Hose	Fuel	0.5
MSIS02	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	60
MSIS03	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
MSIS04	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	Injury	Skid Piping, Tubing, or Hose	Fuel	75
MSIS05	Yes	Turbocharger Casing	Yes	None	Skid Piping, Tubing, or Hose	Lube	Sank
MSIS06	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	30
MSIS07	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Lube	20
MSIS08	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	365
MSIS09	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	0.05
MSIS10	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	0.015
MSIS11	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	Injury	Skid Piping, Tubing, or Hose	Fuel	Not Stated
MSIS12	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Piping	Lube	550
MSIS13	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	5
MSIS14	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Pump	Lube	50
MSIS15	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Duplex Strainer, Filter, or Coalescer	Fuel	1.5
MSIS16	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Lube	Not Stated
MSIS17	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
MSIS18	Yes	Electrical Fixture	No	None	Piping	Fuel	Not Stated
MSIS19	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Duplex Strainer, Filter, or Coalescer	Fuel	0.15
MSIS20	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Valve or Instrument	Fuel	320
MSIS21	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Lube	0.15
MSIS22	Yes	Handheld Torch	No	Fatality	Piping	Fuel	Not Stated
MSIS23	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	Injury	Skid Piping, Tubing, or Hose	Fuel	174
MSIS24	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	1

Incident Number	Ignition	Source of Ignition	Loss of Propulsion or Steering	Human Casualty	Equipment Involved	System Involved	Damage (Thousands of Dollars)
MSIS25	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	30
MSIS26	Yes	Turbocharger Casing	Yes	Injury	Skid Piping, Tubing, or Hose	Fuel	1000
MSIS27	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	650
MSIS28	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	750
MSIS29	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	0.5
MSIS30	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	15
MSIS31	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	40
MSIS32	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	50
MSIS33	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	3.5
MSIS34	Yes	Turbocharger Casing	Yes	None	Skid Piping, Tubing, or Hose	Fuel	50
MSIS35	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	0.1
MSIS36	Yes	Turbocharger Casing	No	Injury	Skid Piping, Tubing, or Hose	Fuel	3
MSIS37	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	Injury	Skid Piping, Tubing, or Hose	Fuel	Not Stated
MSIS38	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	3
LR01	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Lube	Not Stated
LR02	Yes	Turbocharger Casing	Yes	None	Skid Piping, Tubing, or Hose	Lube	Not Stated
LR03	Yes	Hot Surface and/or Open Flame	Yes	None	Piping	Fuel	Constructive Total Loss
LR04	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Vent or Sounding Piping	Fuel	Constructive Total Loss
LR05	Yes	Boiler Explosion	Yes	None	Piping	Fuel	Sank
LR06	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Constructive Total Loss
LR07	Yes	Not Stated	Yes	None	Pump	Lube	Constructive Total Loss
LR08	Yes	Not Stated	Yes	None	Vent or Sounding Piping	Fuel	Not Stated
LR09	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR10	Yes	Steam Line	Yes	None	Valve or Instrument	Lube	Constructive Total Loss
LR11	Yes	Not Stated	Yes	None	Not Stated	Fuel	Not Stated
LR12	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
LR13	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Constructive Total Loss
LR14	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Not Stated	Fuel	Not Stated
LR15	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Valve or Instrument	Lube	Not Stated
LR16	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
LR17	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Vent or Sounding Piping	Fuel	Not Stated
LR18	Yes	Not Stated	Yes	None	Not Stated	Fuel	Constructive Total Loss
LR19	Yes	Not Stated	Yes	None	Valve or Instrument	Fuel	Not Stated
LR20	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
LR21	Yes	Not Stated	Yes	None	Duplex Strainer, Filter, or Coalescer	Lube	Not Stated

Incident Number	Ignition	Source of Ignition	Loss of Propulsion or Steering	Human Casualty	Equipment Involved	System Involved	Damage (Thousands of Dollars)
LR22	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
LR23	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Not Stated	Lube	Not Stated
LR24	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR25	Yes	Not Stated	Yes	None	Not Stated	Fuel	Not Stated
LR26	Yes	Not Stated	Yes	Fatality	Not Stated	Not Stated	Not Stated
LR27	Yes	Not Stated	Yes	None	Pump	Fuel	Not Stated
LR28	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
LR29	Yes	Not Stated	Yes	None	Not Stated	Fuel	Sank
LR30	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Sank
LR31	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Sank
LR32	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Lube	Not Stated
LR33	Yes	Steam Line	Yes	None	Gland Seal Regulator	Lube	Not Stated
LR34	Yes	Not Stated	Yes	None	Not Stated	Fuel	Not Stated
LR35	Yes	Not Stated	No	None	Pump	Fuel	Not Stated
LR36	Yes	Not Stated	Yes	None	Pump	Lube	Not Stated
LR37	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR38	Yes	Not Stated	Yes	Fatality	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR39	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR40	Yes	Not Stated	Yes	None	Duplex Strainer, Filter, or Coalescer	Lube	Not Stated
LR41	Yes	Engine Exhaust Manifold or Exhaust Pipe	No	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
LR42	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK01	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK02	Yes	Not Stated	Not Stated	Not Stated	Valve or Instrument	Fuel	Not Stated
NK03	Yes	Not Stated	Not Stated	Not Stated	Valve or Instrument	Fuel	Not Stated
NK04	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	Fatality	Piping	Fuel	Not Stated
NK05	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK06	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK07	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK08	Yes	Electric Heater	Not Stated	Not Stated	Electric Heater	Fuel	Not Stated
NK09	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Fuel	Not Stated
NK10	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Valve or Instrument	Fuel	Not Stated
NK11	Yes	Not Stated	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK12	Yes	Not Stated	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK13	Yes	Not Stated	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK14	Yes	Not Stated	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK15	Yes	Explosion	Not Stated	Not Stated	Valve or Instrument	Fuel	Not Stated
NK16	Yes	Not Stated	Not Stated	Not Stated	Pump	Fuel	Not Stated
NK17	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK18	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK19	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK20	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK21	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated

Incident Number	Ignition	Source of Ignition	Loss of Propulsion or Steering	Human Casualty	Equipment Involved	System Involved	Damage (Thousands of Dollars)
NK22	Yes	Hot Surface and/or Open Flame	Not Stated	Not Stated	Piping	Fuel	Not Stated
NK23	Yes	Not Stated	Not Stated	Not Stated	Valve or Instrument	Fuel	Not Stated
NK24	Yes	Not Stated	Not Stated	Not Stated	Vent or Sounding Piping	Fuel	Not Stated
NK25	Yes	Not Stated	Not Stated	Not Stated	Vent or Sounding Piping	Fuel	Not Stated
NK26	Yes	Not Stated	Not Stated	Not Stated	Vent or Sounding Piping	Fuel	Not Stated
NK27	Yes	Hot Surface or Electrical Equipment	Not Stated	Not Stated	Vent or Sounding Piping	Fuel	Not Stated
NK28	Yes	Not Stated	Not Stated	Not Stated	Engine	Fuel	Not Stated
NK29	Yes	Not Stated	Not Stated	Not Stated	Engine	Fuel	Not Stated
NK30	Yes	Not Stated	Not Stated	Not Stated	Purifier	Fuel	Not Stated
NK31	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Lube	Not Stated
NK32	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Skid Piping, Tubing, or Hose	Lube	Not Stated
NK33	Yes	Explosion	Not Stated	Not Stated	Engine	Lube	Not Stated
NK34	Yes	Turbocharger Casing	Not Stated	Fatality	Duplex Strainer, Filter, or Coalescer	Lube	Not Stated
NK35	Yes	Not Stated	Not Stated	Not Stated	Valve or Instrument	Lube	Not Stated
NK36	Yes	Not Stated	Not Stated	Not Stated	Vent or Sounding Piping	Lube	Not Stated
NK37	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Fatality	Duplex Strainer, Filter, or Coalescer	Lube	Not Stated
NK38	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Duplex Strainer, Filter, or Coalescer	Lube	Not Stated
NK39	Yes	Engine Exhaust Manifold or Exhaust Pipe	Not Stated	Not Stated	Vent or Sounding Piping	Fuel	Not Stated
TSB01	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Duplex Strainer, Filter, or Coalescer	Fuel	Not Stated
TSB02	Yes	Not Stated	Yes	None	Not Stated	Not Stated	Not Stated
MIIU01	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Not Stated
MIIU02	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Lube	Not Stated
MIIU03	Yes	Engine Exhaust Manifold or Exhaust Pipe	Yes	None	Skid Piping, Tubing, or Hose	Fuel	Sank
NTSB01	Yes	Turbocharger Casing	Yes	Fatality	Duplex Strainer, Filter, or Coalescer	Lube	Constructive Total Loss
NTSB02	Yes	Steam Line	Yes	Fatality	Duplex Strainer, Filter, or Coalescer	Lube	2000
NTSB03	Yes	Steam Line	Yes	Fatality	Duplex Strainer, Filter, or Coalescer	Fuel	Constructive Total Loss

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APPENDIX J

Evaluation of the Impact of Preliminary Recommendations

Incident Number	1. Monolithic Engine	2. Pipe Sheathing	3. Hot Surface Sheathing	4. Deflective Shielding for Strainer/Filter/Coalescer	5. Water Cooled Injectors	6. Better Positioning of Flexible Joints	7. Use of Flexible Joints for Top-Fired Boilers	8. Reinforced Sight Glasses for Oil Tanks	9. Route FO/LO Tank Vents Outside the Engine Room	10. No FO/LO Tanks Above Hot Surfaces	11. No Steam Blow Piping in FO/LO Tanks	12. Safe Location for DB Sounding Pipes	13. Closed Gaging for FO/DB Tanks	14. Self-cleaning Strainer/Filter/Coalescer	15. Safety/Reliability Data Systems	16. Hazard Analyses for FO/LO Systems	17. Management of Change System	18. Standard Operating Procedures	19. Safe Work Practices	20. Training Program	21. Quality/Mechanical Integrity	22. Pre-startup Safety Review Program	23. Emergency Response/Control Program	24. Accident Investigation Program	25. Safety/Reliability Audit Program	26. Fine Water Mist System	27. Robust Fittings	28. Electronic Instrumentation	All	Comments
MISREP01	C	E	D	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	C	
MISREP02	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP03	E	C	C	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	E	E	B	E	B	Lack of mechanical robustness for the connection was a clear contributor to this event
MISREP04	E	C	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	B	
MISREP06	E	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	
MISREP08	E	E	E	E	E	E	E	E	E	E	E	E	E	A	E	E	E	E	C	D	E	E	E	E	E	E	E	E	A	
MISREP09	E	E	E	E	E	E	E	E	E	E	E	E	E	A	E	E	E	E	C	D	E	E	E	E	E	E	E	E	A	Similar to MISREP08
MISREP10	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	
MISREP11	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP13	E	E	E	E	E	E	E	E	E	E	E	E	E	A	E	E	E	E	C	D	E	E	E	E	E	E	E	E	A	Similar to MISREP08
MISREP14	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	E	E	E	E	E	E	E	E	E	C	
MISREP15	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP16	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP17	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	Similar to MISREP10
MISREP19	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Cracked filter. A deflector shielding prevented the spray of oil
MISREP20	E	C	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	B	Similar to MISREP03, but the cause of cracking is unknown
MISREP21	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	B	E	B	Lack of mechanical robustness for the connection was a clear contributor to this event
MISREP22	E	D	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	E	E	E	E	E	E	E	E	D	Gasket failure
MISREP23	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP24	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	D	E	D	Similar to MISREP03, but the cause of the leak is improper gasket
MISREP25	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP28	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	

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MISREP29	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Similar to MISREP19
MISREP30	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	
MISREP31	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP32	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	D	E	C	
MISREP33	I	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	E	I	The cause of the leak was not stated
MISREP34	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	D	Similar to MISREP22. The existing flange deflector shielding prevented spray onto hot surfaces and personnel
MISREP35	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	No exterior weld around the end fitting of a fuel line
MISREP36	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	D	
MISREP37	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP38	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	D	E	C	Similar to MISREP03, but it involved a hose connection failure
MISREP40	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Similar to MISREP03. A flange shield prevented spray
MISREP41	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP42	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP43	E	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	D	
MISREP44	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP45	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	D	
MISREP46	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP47	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	C	
MISREP48	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP49	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	Similar to MISREP19
MISREP50	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	Similar to MISREP10
MISREP51	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
MISREP52	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	E	E	E	E	E	E	E	D	

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MISREP53	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E	D	
MISREP54	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	
MISREP55	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	D	Similar to MISREP22
MSIS01	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	D	E	C	Similar to MIIU01, but small fire caused minor injury
MSIS02	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	C	Similar to MIIU01, but emergency response was more effective
MSIS03	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS04	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS05	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	I	E	D	Similar to MISREP03, but emergency response and fire protection were inadequate
MSIS06	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01; damage > 25,000
MSIS07	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS08	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	D	D	E	C	This fire was either intentionally set or a fuel line ruptured, spraying fuel onto the exhaust manifold and causing the fire. We assumed the latter for the purpose of analysis
MSIS09	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS10	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	E	E	E	E	C	E	E	E	E	E	D	E	C	
MSIS11	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	C	E	C	Similar to MIIU01, but emergency response was more effective

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MSIS12	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	E	E	E	D	E	E	E	E	E	E	D	E	C	Damage > 500,000. Lube oil lines for the air deck compressor leaked, allowing oil to drip down onto the diesel engine in the deck below the compressor
MSIS13	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	E	E	C	Similar to MIIU01, but emergency response was more effective
MSIS14	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	
MSIS15	E	D	D	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	Similar to MISREP19, but the release ignited
MSIS16	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	I	E	E	E	E	E	I	E	C	Similar to MISREP03. Assumed this was the engine lube oil system
MSIS17	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS18	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	Ignited by electrical fixtures. This is a rare fire that was not ignited by "hot surface"
MSIS19	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	D	E	E	E	E	E	E	E	D	Example of lagging and insulation failing to prevent ignition
MSIS20	E	E	D	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	D	E	B	
MSIS21	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	Similar to MISREP03. Assumed this was the engine lube oil system
MSIS22	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	B	D	E	E	E	E	E	E	E	E	B	
MSIS23	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	D	E	E	D	E	E	C	Similar to MIIU01. The incident report stated that this fire could have been prevented if lagging, deflector plates, or a guard had been installed to protect the hot exhaust manifold and turbocharger

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MSIS24	E	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	E	E	E	E	E	E	E	A	A	The crew used a fire hose to produce a water mist that allowed an engineer to shut off fuel. The line that failed had been replaced two days before the incident. The crew used a plastic line instead of the original plastic-coated steel line.
MSIS25	C	E	D	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	D	D	E	E	E	E	D	E	E	C	
MSIS26	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	D	E	C	
MSIS27	E	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	C	E	B	Lack of mechanical robustness for the connection was a clear contributor to this event
MSIS28	E	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	C	
MSIS29	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS30	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS31	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS32	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS33	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	E	C	Similar to MIIU01, but emergency response was more effective
MSIS34	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	C	Similar to MIIU01, but emergency response was more effective
MSIS35	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	I	E	C	Similar to MIIU01, but emergency response was more effective
MSIS36	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	I	E	C	Similar to MIIU01, but emergency response was more effective

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MSIS37	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	I	E	C	Similar to MIIU01, but emergency response was more effective
MSIS38	C	D	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	I	E	C	Similar to MIIU01, but emergency response was more effective
LR01	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	I	E	D	Similar to MISREP03, but assumed emergency response and fire protection were inadequate
LR02	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	I	E	D	Similar to MISREP03, but assumed emergency response and fire protection were inadequate
LR03	E	I	I	E	E	E	E	E	E	I	E	E	E	E	E	I	I	I	I	I	E	E	I	E	E	I	E	E	I	
LR04	E	E	D	E	E	E	E	E	A	I	E	D	E	E	E	D	E	I	I	D	E	E	I	E	E	E	E	E	A	
LR05	E	E	E	E	E	I	E	E	E	I	I	E	E	E	E	I	I	I	I	I	I	E	I	E	E	E	E	E	I	
LR06	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	D	D	E	C	
LR07	E	E	I	E	E	E	E	E	E	I	E	E	E	E	E	I	I	E	E	I	E	E	I	E	E	E	E	E	E	
LR08	E	E	D	E	E	E	E	E	E	I	E	D	C	E	E	D	E	E	C	D	E	E	I	E	E	E	E	E	C	
LR09	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	D	D	E	C	
LR10	E	E	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	E	E	D	
LR11	I	I	I	I	E	E	I	E	E	I	E	E	E	E	I	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR12	I	I	I	I	I	E	I	I	E	I	I	E	E	I	I	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR13	I	I	I	I	I	E	I	I	E	I	I	E	E	I	I	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR14	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	D	E	C	
LR15	E	E	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	D	E	D	
LR16	I	I	I	I	I	E	I	I	I	I	I	E	E	I	I	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR17	E	E	D	E	E	E	E	E	E	I	E	D	C	E	E	D	E	E	C	D	E	E	I	E	E	E	E	E	C	
LR18	I	I	I	I	I	E	I	E	E	I	E	E	E	E	E	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR19	E	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	
LR20	I	I	I	I	I	E	I	I	E	I	I	I	I	I	E	I	I	I	I	I	I	E	I	E	E	I	I	I	I	

Incident Number	1. Monolithic Engine	2. Pipe Sheathing	3. Hot Surface Sheathing	4. Deflective Shielding for Strainer/Filter/Coalescer	5. Water Cooled Injectors	6. Better Positioning of Flexible Joints	7. Use of Flexible Joints for Top-Fired Boilers	8. Reinforced Sight Glasses for Oil Tanks	9. Route FO/LO Tank Vents Outside the Engine Room	10. No FO/LO Tanks Above Hot Surfaces	11. No Steam Blow Piping in FO/LO Tanks	12. Safe Location for DB Sounding Pipes	13. Closed Gaging for FO/DB Tanks	14. Self-cleaning Strainer/Filter/Coalescer	15. Safety/Reliability Data Systems	16. Hazard Analyses for FO/LO Systems	17. Management of Change System	18. Standard Operating Procedures	19. Safe Work Practices	20. Training Program	21. Quality/Mechanical Integrity	22. Pre-startup Safety Review Program	23. Emergency Response/Control Program	24. Accident Investigation Program	25. Safety/Reliability Audit Program	26. Fine Water Mist System	27. Robust Fittings	28. Electronic Instrumentation	All	Comments
LR21	E	E	D	C	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	E	E	C	Assumed filter failed because of external impact
LR22	I	I	I	I	I	E	I	I	E	I	I	E	E	I	E	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR23	C	I	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	I	I	C	
LR24	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	I	I	C	
LR25	I	I	I	E	I	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	E	I	I	I	
LR26	E	E	E	E	I	E	E	E	E	I	E	E	E	E	E	I	I	I	I	I	I	E	I	E	E	E	E	E	I	
LR27	E	E	I	E	E	E	E	E	E	I	E	E	E	E	E	E	I	E	E	I	I	E	I	E	E	E	E	E	I	
LR28	I	I	I	I	I	E	I	I	E	I	I	E	E	I	I	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR29	I	I	I	E	I	E	I	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	E	I	I	I	
LR30	I	I	I	I	I	E	I	I	E	I	I	E	E	I	E	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR31	I	I	I	I	I	E	I	I	E	I	I	E	E	I	E	I	I	I	I	I	I	E	I	E	E	I	I	I	I	
LR32	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	D	I	E	D	Similar to MISREP03, but the release ignited
LR33	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
LR34	I	I	I	E	I	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	I	I	I	
LR35	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	E	E	E	C	
LR36	E	D	D	E	E	E	E	E	E	I	E	E	E	E	E	I	I	I	I	I	E	E	I	E	E	I	E	E	D	
LR37	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	D	E	C	
LR38	I	D	I	E	I	E	I	E	E	I	E	E	E	E	E	I	I	I	I	I	E	E	I	E	E	I	I	E	D	
LR39	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	D	E	C	
LR40	E	D	D	C	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	E	E	I	E	E	I	E	E	C	Similar to MISREP22, but the release ignited
LR41	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	D	E	C	
LR42	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	I	E	C	
NK01	E	E	D	E	E	E	E	E	E	I	E	E	E	E	E	I	E	I	E	I	I	E	I	E	E	I	E	E	D	
NK02	E	I	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	E	E	D	
NK03	E	I	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	D	E	D	

Incident Number	1. Monolithic Engine	2. Pipe Sheathing	3. Hot Surface Sheathing	4. Deflective Shielding for Strainer/Filter/Coalescer	5. Water Cooled Injectors	6. Better Positioning of Flexible Joints	7. Use of Flexible Joints for Top-Fired Boilers	8. Reinforced Sight Glasses for Oil Tanks	9. Route FO/LO Tank Vents Outside the Engine Room	10. No FO/LO Tanks Above Hot Surfaces	11. No Steam Blow Piping in FO/LO Tanks	12. Safe Location for DB Sounding Pipes	13. Closed Gaging for FO/DB Tanks	14. Self-cleaning Strainer/Filter/Coalescer	15. Safety/Reliability Data Systems	16. Hazard Analyses for FO/LO Systems	17. Management of Change System	18. Standard Operating Procedures	19. Safe Work Practices	20. Training Program	21. Quality/Mechanical Integrity	22. Pre-startup Safety Review Program	23. Emergency Response/Control Program	24. Accident Investigation Program	25. Safety/Reliability Audit Program	26. Fine Water Mist System	27. Robust Fittings	28. Electronic Instrumentation	All	Comments
NK04	E	E	D	E	E	E	E	E	E	I	E	E	E	E	E	E	D	E	E	D	E	E	I	E	E	I	I	I	D	
NK05	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	E	E	C	See NK06
NK06	E	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	E	E	D	
NK07	E	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	E	E	D	See NK06
NK08	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	
NK09	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	I	E	E	I	E	E	C	See NK05 and NK06
NK10	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	C	E	E	D	D	E	I	E	E	I	D	E	C	
NK11	E	D	D	E	A	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	I	E	I	E	E	I	E	E	A	
NK12	E	D	D	E	A	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	I	E	I	E	E	I	E	E	A	
NK13	E	D	D	E	A	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	I	E	I	E	E	I	E	E	A	
NK14	E	D	D	E	A	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	I	E	I	E	E	I	E	E	A	
NK15	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	D	E	D	
NK16	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	E	E	C	
NK17	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	I	D	E	I	D	E	I	E	E	E	E	E	D	
NK18	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	I	D	E	I	D	E	I	E	E	E	E	E	D	
NK19	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	I	D	E	I	D	E	I	E	E	E	E	E	D	
NK20	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	I	D	E	I	D	E	I	E	E	E	E	E	D	
NK21	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	D	I	D	E	I	D	E	I	E	E	E	E	E	D	
NK22	E	D	D	E	E	E	D	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	E	D	E	D	
NK23	E	E	D	E	E	E	E	C	E	I	E	E	E	E	E	D	E	E	E	I	I	E	I	E	E	E	E	E	C	
NK24	E	E	D	E	E	E	E	E	A	I	E	E	E	E	E	C	E	D	C	D	E	E	I	E	E	E	E	E	A	
NK25	E	E	D	E	E	E	E	E	A	I	E	E	E	E	E	C	E	D	C	D	E	E	I	E	E	E	E	E	A	Similar to LR04
NK26	E	E	D	E	E	E	E	E	E	I	E	D	A	E	E	D	E	D	C	D	E	E	I	E	E	E	E	E	A	
NK27	E	E	D	E	E	E	E	E	E	I	E	D	A	E	E	D	E	D	C	D	E	E	I	E	E	E	E	E	A	Similar to NK26
NK28	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	E	E	E	
NK29	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	E	E	E	I	E	E	I	E	E	E	
NK30	E	D	D	D	E	E	E	E	E	I	E	E	E	E	E	E	E	C	E	D	E	E	I	E	E	I	E	E	C	

Incident Number	1. Monolithic Engine	2. Pipe Sheathing	3. Hot Surface Sheathing	4. Deflective Shielding for Strainer/Filter/Coalescer	5. Water Cooled Injectors	6. Better Positioning of Flexible Joints	7. Use of Flexible Joints for Top-Fired Boilers	8. Reinforced Sight Glasses for Oil Tanks	9. Route FO/LO Tank Vents Outside the Engine Room	10. No FO/LO Tanks Above Hot Surfaces	11. No Steam Blow Piping in FO/LO Tanks	12. Safe Location for DB Sounding Pipes	13. Closed Gaging for FO/DB Tanks	14. Self-cleaning Strainer/Filter/Coalescer	15. Safety/Reliability Data Systems	16. Hazard Analyses for FO/LO Systems	17. Management of Change System	18. Standard Operating Procedures	19. Safe Work Practices	20. Training Program	21. Quality/Mechanical Integrity	22. Pre-startup Safety Review Program	23. Emergency Response/Control Program	24. Accident Investigation Program	25. Safety/Reliability Audit Program	26. Fine Water Mist System	27. Robust Fittings	28. Electronic Instrumentation	All	Comments
NK31	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	D	E	C	Similar to MISREP03, but the release ignited
NK32	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	D	E	C	Similar to MISREP03, but the release ignited
NK33	E	E	E	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	I	E	I	E	E	I	E	E	E	
NK34	E	D	D	C	E	E	E	E	E	I	E	E	E	D	E	E	E	E	E	D	E	E	I	E	E	D	E	E	B	
NK35	E	E	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	I	I	E	I	E	E	I	E	E	D	
NK36	E	E	D	E	E	E	E	E	D	D	E	D	I	E	E	D	E	C	E	D	E	E	I	E	E	I	E	E	C	
NK37	E	E	D	C	E	E	E	E	E	I	E	E	E	A	E	C	E	E	E	D	C	E	I	E	E	D	E	E	A	
NK38	E	E	D	C	E	E	E	E	E	I	E	E	E	A	E	D	E	E	E	D	E	E	I	E	E	D	E	E	A	
NK39	E	E	D	E	E	E	E	E	E	I	E	D	A	E	E	D	E	D	C	D	A	E	I	E	E	E	E	E	A	
TSB01	E	E	D	C	E	E	E	E	E	I	E	E	E	A	E	C	D	E	C	D	D	E	D	E	E	D	E	E	A	
TSB02	I	I	I	I	E	I	I	I	E	I	E	E	E	E	E	I	I	I	I	E	E	E	D	E	E	D	I	I	D	
MIIU01	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	D	E	E	E	D	E	C	
MIIU02	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	E	E	E	E	E	E	E	C	
MIIU03	C	D	D	E	E	E	E	E	E	I	E	E	E	E	E	E	E	E	E	D	D	E	E	E	E	E	D	I	C	
NTSB01	E	E	D	C	E	E	E	E	E	E	E	E	E	A	E	E	E	E	E	D	E	E	D	E	E	C	E	E	A	
NTSB02	E	E	D	C	E	E	E	E	E	I	E	E	E	A	E	E	E	E	C	D	E	E	D	E	E	C	E	E	A	
NTSB03	E	E	D	C	E	E	E	E	E	E	E	E	E	A	E	C	E	E	E	E	A	E	E	E	E	C	D	E	A	

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APPENDIX K

Résumés of Hazard Evaluation Team Members

GEORGE C. CASSA
Vice President
CG International, Inc.
Scotch Plains, New Jersey

EDUCATION

M.S. Management Science, Stevens Institute of Technology, 1979.

B.S. Marine Engineering, United States Merchant Marine Academy, 1969.

CERTIFICATION

Licensed by the United States Coast Guard as Third Assistant Engineer of steam and motor vessels.

SUMMARY OF EXPERIENCE

1986 - Present CG International, Inc. Mr. Cassa joined CG International, Inc. when the firm was established in 1986. Representative assignments have included the following:

Flag Change and Foreign Construction to U.S. Standards:

- Review, modification, and submittal of shipyard plans for U.S.-flag recertification of Danish-, German-, and Japanese-built RO/RO-container ship for Maersk Line Ltd.

- Review, modification, and submittal of shipyard plans for conversion and U.S.-flag recertification of a seismic survey vessel constructed in Canada to oceanographic research ship for Lamont-Doherty Geological Observatory of Columbia University

Plans and Specifications Development:

- Bid specifications for construction of new cable-laying vessels for Transoceanic Cable Ship Company

- Contract specifications and guidance plans for conversion of general cargo vessel to oceangoing barge for Lykes Bros. Steamship Company

Detailed Design Review and Approval:

- Review and approval of shipyard automation and electrical plans for LNG tankers under construction at IHI Aichi shipyard for Phillips/Marathon

1974 - 1986	J.J. Henry Co., Inc. Mr. Cassa joined the company as a marine engineer in the New York office. He was responsible for developing and reviewing machinery plans and specifications for a variety of commercial marine clients. In addition, he prepared technical feasibility analyses and economic evaluation studies of shipboard machinery components and systems. He was promoted to Chief Marine Engineer in 1985.
1971 - 1974	Bailey Meter Company. As a field sales/service technical representative, Mr. Cassa's experience included onsite installation and startup supervision of propulsion plant instrumentation and control systems, proposal work, and sales solicitation duties.
1969 - 1971	American Export Lines. Mr. Cassa sailed as a licensed Third Assistant Engineer aboard the company's geared steam turbine C-3 type general cargo vessels and C-5 type automated container ships.

HENRIQUE M. PAULA
Senior Technical Director
Senior Engineer III

EDUCATION

Ph.D.	Nuclear Engineering, University of Tennessee, Knoxville, Tennessee, 1984. (Course work and dissertation focused on systems reliability and risk assessment.)
M.S.	Nuclear Engineering, Universidade de São Paulo, São Paulo, Brazil, 1979.
B.S.	Electrical Engineering, Instituto Nacional de Telecomunicações, Santa Rita do Sapucaí, Minas Gerais, Brazil, 1977.

SUMMARY OF EXPERIENCE

Dr. Paula has 20 years of engineering experience, including 14 years performing process safety management (PSM) activities, probabilistic or quantitative risk assessments (PRAs/QRAs), process hazard analyses (PHAs), hazard and operability (HAZOP) analyses, failure modes and effects analyses (FMEAs), event tree analyses, fault tree analyses (FTAs), quantitative external event (hurricane, tornado, aircraft crash, etc.) analyses, and consequence (hazardous material release rates, dispersion modeling, vapor cloud explosion modeling, etc.) analyses. He has performed safety and hazard evaluations in a variety of industries, including offshore oil/gas, petrochemical, chemical, nuclear, defense, manufacturing, and mining industries and provided consulting/training services in 12 countries.

Dr. Paula has authored or coauthored over 100 documents on risk analysis, including journal articles, conference papers, technical reports, and sections of *Guidelines for Chemical Process Quantitative Risk Assessment*, Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AIChE); *Procedures for Treating Common Cause Failures in Safety and Reliability Studies*, Electric Power Research Institute (EPRI) and the U.S. Nuclear Regulatory Commission (NRC); and *Procedures for Conducting Probabilistic Safety Assessments for Nuclear Power Plants (Level 1)*, International Atomic Energy Agency (IAEA).

1987 - Present

Project Manager, Senior Engineer (since 1991), and Senior Technical Director (since 1996), JBF Associates, Inc. (JBFA) and Process Safety Institute (PSI). Acts as a project manager and senior technical advisor for JBFA projects. Performed these functions and hazard evaluations, risk assessments, and reliability analyses for industrial customers. Managed, acted as a leader, and/or otherwise participated in about 70 projects involving a variety of technology in several industries, including:

- Oil production and exploration
- Oil refining, including crude distillation, fluidized catalytic cracking (FCC), hydrogen fluoride (HF) alkylation, hydrotreating, isomerization, sulfur recovery, amine plant, tail gas treating
- Petrochemical, including benzene, toluene, and xylene (BTX), polypropylene, and polyethylene

- Chemical, including phenol (cumene hydroperoxide decomposition), polyols, propylene oxide/tertiary butyl alcohol (PO/TBA) oxidation, butyraldehyde, methyl mercaptan, ammonia, and bleach plants
- Transportation, including steering and propulsion systems on oil tankers
- Waste disposal, including chemical demilitarization and low-level transuranic
- Mining, including mining operations, extraction, concentration, smelting, and refining
- Fire protection, including underground piping systems
- Electrical power generation and distribution systems
- Powerhouse and utilities at industrial sites, including water systems (raw, service, cooling, etc.), cooling towers, steam, air, nitrogen, and natural gas
- Manufacturing, including automobile and household products
- Paper mill
- Industrial control system, including programmable logic controllers and fault-tolerant distributed control systems (F-T DCSs)
- Computer system, including local area network (LAN)
- Nuclear power/research, including pressurized water reactor (PWR), boiling water reactor (BWR), heavy water reactor (HWR), gas-cooled reactor, and research reactor
- Nuclear fuel and waste, including freezer/sublimer and lid closure mechanism for transportation cask

Develops and teaches courses for PSI, AIChE, and Zurich-American. Also lectured for the IAEA on PRA methods and applications at the Herald Research Reactor (Santiago, Chile, July 1994), Paks Nuclear Power Plant (NPP) (Paks, Hungary, March 9-13, 1992), Argonne National Laboratory (Argonne, IL, March 1988, March 1991, and January 1992), and Korea Atomic Energy Research Institute (Daeduk-Danji, Taejon, Republic of Korea, October 30-November 3, 1995, and December 2-6, 1991). Additionally, acted as a consultant for the IAEA in the review of the PRAs for the Atucha-1 NPP (Argentina, April 29-May 10, 1996, and December 6-17, 1993), Angra-1 NPP (Brazil, November 9-13, 1992), and the Krsko NPP (Slovenia, May 20-24, 1991).

Helps develop software for hazard analysis and risk assessment. Managed the development of **SARPA** and **AUDITOR**, state-of-the-art Windows® programs for qualitative and quantitative analysis/audit of management systems (organizational factors) at large industrial complexes (e.g., oil refinery). Developed the technical and mathematical specifications for **BRAVO™2.0**, a state-of-the-art Windows program for performing event tree and fault tree analyses. Also managed the development of and prepared the technical specifications for **QRA ROOTS™**, a Windows program for storing, searching

for, and retrieving equipment failure/repair data, human error probability, and external event (fire, flood, etc.) frequency.

1984 - 1987 Research Scientist and Systems Engineer, JBF Associates, Inc. Developed methods for applying PRA results to NRC inspection activities, and participated in the development of the Plant Risk Status Information Management System (PRISIM) computer program. Consultant to the IAEA during an international PRA conference held in Vienna, Austria, in June 1987. Performed a variety of tasks (plant systems analysis, data analysis, common cause failure (CCF) analysis, accident sequence analysis, and recovery analysis) in the review and update of the Arkansas Nuclear One — Unit 1, the Peach Bottom — Unit 2, and the CONUS Demilitarization Facilities PRAs. Developed analysis methods for the NRC, Sandia National Laboratories (SNL), Oak Ridge National Laboratory (ORNL), and Idaho National Engineering Laboratory (INEL). Provided engineering services to SNL and to the NRC in the area of CCF analysis, and performed an uncertainty analysis for the INEL regarding daily use of updated PRA/QRA information. Duties also included the development and application of methods for relating PRA information to NRC inspection procedures, generation of a dependent failure analysis procedures guide, collection and analysis of dependent failure data, and collection and analysis of failures of nuclear reactor components caused by harsh environments.

1980 - 1983 Full-time graduate student at the University of Tennessee, Knoxville, Tennessee. Held a teaching assistantship and supervised students attending a computer-aided FORTRAN course.

1978 - 1979 Research Specialist, Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo, Brazil. Performed engineering analyses in support of IPEN's High-Temperature Gas-Cooled Reactor (HTGR) experiments. Developed a methodology and a computer program to simulate the thermal response of IPEN's HTGR experimental facility. This program evaluates several parameters, including the time necessary to perform the experiments. It was developed as a decision-making tool for scheduling experiments and for allocating manpower.

PROFESSIONAL ACTIVITIES

Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119 (Training Course), Process Safety Institute, Knoxville, TN, 1993.

Hazard Evaluation: Consequence Analysis Methods (Training Course), Process Safety Institute, Knoxville, TN, 1993.

Guest editor of a special issue of the journal *Reliability Engineering and System Safety*, addressing the reliability performance, analysis, and evaluation of programmable electronic systems (Vol. 39, 1993).

Methods for Calculation of Fire and Explosion Hazards (Training Course), AIChE, August 7-8, 1992.

Hazard and Operability Analysis (Training Course), Process Safety Institute, Knoxville, TN, January 21-24, 1992.

Recipient of the *Professional Initiative Award*, JBF Associates, Inc., 1984, and the *Dedicated Service Award*, JBF Associates, Inc., 1991.

Invited speaker at the Society of Fire Protection Engineers to discuss the use of risk assessment, Oak Ridge, TN, January 10, 1991.

U.S. participant in the IAEA's 3-year *Coordinated Research Programme on Data Collection and Analysis for Probabilistic Safety Analysis*, held in Athens, Greece, February 1989, and in Vienna, Austria, March 1988 and April 1990.

Certified Reliability Analyst, JBF Associates, Inc., 1989.

Human Reliability in Engineered Systems Analysis (Training Course), JBF Associates, Inc., 1988.

PUBLICATIONS AND PRESENTATIONS

"Improving the Reliability and Safety of Computerized Systems in Hydrocarbon Processes," *The International Journal of Hydrocarbon Engineering*, to be published in February 1998.

"Accounting for Common Cause Failures When Assessing the Effectiveness of Safeguards," *CCPS/AIChE International Conference and Workshop on Risk Analysis in Process Safety*, Atlanta, GA, October 1997.

"QRA of Chemical Reaction Systems - The State of the Practice," *Process Safety Progress*, Vol. 16, No. 4, Winter 1997. Also presented at the *31st Annual Loss Prevention Symposium*, AIChE 1997 Spring National Meeting, Houston, TX, March 1997.

"On the Definition of Common Cause Failure," *Nuclear Safety*, Vol. 36, No. 1, January-June 1995.

"Probabilistic Safety Analysis for Systems with Standby Subsystems with Frequently Used Standbys," *Reliability Engineering and System Safety*, Vol. 44, No. 1, 1994.

"Analysis of Uncertainties in Interactive Probabilistic Safety Analysis (PSA) Models," *Risk Analysis*, Vol. 13, No. 2, 1993.

"Reliability Performance, Analysis, and Evaluation of Programmable Electronic Systems, with Emphasis in Chemical Process Applications" (Guest Editorial), *Reliability Engineering and System Safety*, Vol. 39, 1993.

"Operational Failure Experience of Fault-Tolerant Digital Control Systems," *Reliability Engineering and System Safety*, Vol. 39, 1993.

"Failure Rates for Programmable Logic Controllers," *Reliability Engineering and System Safety*, Vol. 39, 1993.

Enhancements to Data Collection and Reporting of Single and Multiple Failure Events, NUREG/CR-5471 (SAND89-2562), U.S. Nuclear Regulatory Commission, Washington, DC, March 1993.

Procedures for Conducting Probabilistic Safety Assessments for Nuclear Power Plants (Level 1), Safety Series No. 50-P-4, International Atomic Energy Agency, Vienna, Austria, 1992.

"Scheduling Updates of Probabilistic Risk Assessments: The Arkansas Nuclear One - Unit 1 Experience," *Risk Analysis*, Vol. 12, No. 2, June 1992 (with V. H. Guthrie and D. J. Campbell). Also published as "Scheduling PRA Updates: The ANO-1 Experience," *Transactions of the American Nuclear Society's 1991 Annual Meeting*, held June 2-6, 1991, in Orlando, FL, Vol. 63, the American Nuclear Society, Inc., La Grange Park, IL, June 1991.

"Qualitative Cause-Defense Matrices: Engineering Tools to Support the Analysis and Prevention of Common Cause Failures," *Reliability Engineering and System Safety*, Vol. 34, No. 3, 1991.

"Reliability Performance of Fault-Tolerant Digital Control Systems," *Plant/Operations Progress*, Vol. 10, No. 2, April 1991. Also published and presented at the following conferences:

- *Proceedings of the Process Control Forum*, sponsored by the Chemical Manufacturers Association, San Antonio, TX, April 1992.
- *Proceedings of the 24th Annual Loss Prevention Symposium*, AIChE, San Diego, CA, August 1990.
- Third coordination meeting of the IAEA's *Research Programme on Data Collection and Analysis for PSA*, Vienna, Austria, April 2-5, 1990.

"Data Needs for Common Cause Failure Analysis," *Proceedings of the International Conference on Probabilistic Safety Assessment and Management*, held February 4-7, 1991, at the University of California at Los Angeles, Beverly Hills, CA, published by Elsevier Science Publishing Co., Inc., New York, NY, February 1991.

"Analysis of Uncertainties Associated with the Numerical Results Evaluated by Interactive Computational PRA Models," *Proceedings of the First International Symposium on Uncertainty Modeling and Analysis*, held December 3-5, 1990, at the University of Maryland, College Park, MD, published by IEEE Computer Society, Los Alamitos, CA 90720-1264, December 1990.

"Facility Risk Review as an Approach to Prioritizing Loss Prevention Efforts," *Plant/Operations Progress*, Vol. 9, No. 4, October 1990. Also presented at the American Institute of Chemical Engineers 1990 Spring National Meeting, Orlando, FL, March 1990.

A Cause-Defense Approach to the Understanding and Analysis of Common Cause Failures, NUREG/CR-5460 (SAND89-2368), U.S. Nuclear Regulatory Commission, Washington, DC, March 1990.

"NRC Research in Common Cause Failures," *Proceedings of the U.S. Nuclear Regulatory Commission Sixteenth Water Reactor Safety Information Meeting*, NUREG/CP-0097, Vol. 1, March 1989.

"Data Base Features That Are Needed to Support Common Cause Failure Analysis and Prevention: An Analyst's Perspective," *Nuclear Safety*, Vol. 31, No. 2, April-June 1990, also presented at the second coordination meeting of the *International Atomic Energy Agency's Research Programme on Data Collection and Analysis for PSA*, Athens, Greece, February 13-17, 1989.

"Common Cause Failure Analysis," Section 3.3.1 (pages 221 through 237), *Guidelines for Chemical Process Quantitative Risk Analysis*, published by the Center for Chemical Process Safety of the American Institute of Chemical Engineers, New York, NY, 1989.

Procedures for Treating Common Cause Failures in Safety and Reliability Studies (Vol. II: Analytical Background and Techniques), NUREG/CR-4780, EPRI NP-5613, U.S. Nuclear Regulatory Commission, Washington, DC, and the Electric Power Research Institute, Palo Alto, CA, January 1989.

"A Probabilistic Dependent Failure Analysis of a D-C Electric Power System in a Nuclear Power Plant," *Nuclear Safety*, Vol. 29, No. 2, April-June 1988.

User's Guide for PRISIM Arkansas Nuclear One — Unit 1, Vol. 1: Program for Inspectors, NUREG/CR-5021 (ORNL/TM-10604), U.S. Nuclear Regulatory Commission, Washington, DC, March 1988.

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"A Restructured Approach to the Partial Beta Factor Method" (unpublished paper), JBF Associates, Inc., Knoxville, TN, October 1986.

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"Letter to the Editor: Comments on 'On the Analysis of Dependent Failures in Risk Assessment and Reliability Evaluation' in Vol. 26, No. 3," *Nuclear Safety*, Vol. 27, No. 2, April-June 1986.

A Methodology for a Time-Dependent Analysis of Accident Sequences and Complex Reactor Systems, Ph.D. dissertation, the University of Tennessee, Knoxville, TN, December 1984.

Desenvolvimento de Modelo de Simulação de Transientes Térmicos no Circulador de Hélio do CNEN (in Portuguese), master's thesis, Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo, Brazil, 1979.

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A Hazard Analysis of a Chlorine Absorption Process, JBFA-175-96, JBF Associates, Inc., October 1997.

Simplified Dust Dispersion Modeling for Steel Mill, JBFA-LR-400-97, JBF Associates, Inc., Knoxville, TN, October 1997.

Task 1 Letter Report — General Spray Protection Investigation, JBFA-LR-101-07-01-94, JBF Associates, Inc., Knoxville, TN, September 1997.

A Methodology and Software for Explicit Modeling of Organizational Performance in Probabilistic Risk Assessment (Report for Task 1 — Methodology Development), JBFA-261.01R-94, JBF Associates, Inc., Knoxville, TN, July 1997.

Review of the Fuel Gas Supply Portion of the HAZOP Analysis for a Power Generating Plant that Uses Sour Gas, JBFA-LR-261-97, JBF Associates, Inc., Knoxville, TN, July 1997.

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A Revalidation of the Process Hazard Analysis of a High Activity Catalyst Polypropylene Plant, JBFA-103.05-95, JBF Associates, Inc., Knoxville, TN, April 1997.

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Report of the Hazard Analysis for the Planned Location of the Control Center at a Carbon Fiber Plant, JBFA-LR-264.02R-95, JBF Associates, Inc., Knoxville, TN, June 1996.

Report of the Hazard Analysis for the Planned Location of a Control Center Common to Multiple Units at a Large Refinery, JBFA-LR-264.01R-95, JBF Associates, Inc., Knoxville, TN, June 1996.

A Process Hazard Analysis of Four Existing Control Centers at a Large Refinery, JBFA-264-95, JBF Associates, Inc., Knoxville, TN, June 1996.

Report of the International Peer Review Service (IPERS), Review Mission for the Atucha-1 Nuclear Power Plant, Probabilistic Safety Assessment (PSA), IAEA-RU-B197 (Distribution Restricted), International Atomic Energy Agency, Vienna, Austria, May 1996.

A Failure Mode and Effects Analysis of the Local Area Network System at a Large Refinery, JBFA-231R-95-27-02, JBF Associates, Inc., Knoxville, TN, March 1996.

A Limited-Scope Failure Mode and Effects Analysis of the Honeywell TDC 3000 at a Large Refinery, JBFA-231R-95-27-01, JBF Associates, Inc., Knoxville, TN, March 1996.

An Availability Analysis of a Chemical Company's MOD5™ Process Control System, JBFA-359-93, JBF Associates, Inc., Knoxville, TN, January 1996.

A PHA of Clay Treating and Aromatics Fractionation Unit 2.1 and Paraxylene Distillation Unit at a Petrochemical Complex, JBFA-137-94, JBF Associates, Inc., Knoxville, TN, October 1995.

Desarollo e Implementación de un Sistema para Administración del Control de Perdidas en La Terminal Marítima Dos Bocas (in Spanish), JBFA-292-94, JBF Associates, Inc., Knoxville, TN, July 1995.

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A Process Hazard Analysis of the Fluid Catalytic Cracking Unit (FCCU) at a Small Refinery, JBFA-336-93, JBF Associates, Inc., Knoxville, TN, February 1995.

A Process Hazard Analysis of a Pentane Isomerization Unit 20 at a Refinery, JBFA-252-94, JBF Associates, Inc., Knoxville, TN, January 1995.

A Process Hazard Analysis of the Light Aromatics Recovery Unit at a Refinery, JBFA-322-93, JBF Associates, Inc., Knoxville, TN, December 1994.

Simplified Quantitative Risk Assessment of the OffPlot HF Storage Tank at a Large Refinery, JBFA-210R2-93, JBF Associates, Inc., Knoxville, TN, December 1994.

Comments on NUREG/CR-6268 (EGG-2709), JBFA-LR-295-94 (HMP-136-94), JBF Associates, Inc., Knoxville, TN, November 1994.

A Review of the Risk Reduction Project for a Large Industrial Manufacturer, JBFA-256-94, JBF Associates, Inc., Knoxville, TN, July 1994.

Report on the Probabilistic Safety Techniques Workshop, Part 2, for the CCEN's Herald Research Reactor in Santiago, Chile, End-of-Mission Report for Project and Task No. CHI/9/019-03, July 1994.

A Process Hazard Analysis of the Distillate Hydrotreater (DHT) at a Large Refinery, JBFA-306-92, JBF Associates, Inc., Knoxville, TN, May 1994.

Review of the Probabilistic Safety Analysis (PSA) Study for the Atucha-1 Nuclear Power Plant, Task No. ARG/9/006-08, International Atomic Energy Agency, Vienna, Austria, March 1994.

A Process Hazard Analysis of Sulfur Recovery Unit II and a Tail Gas Treating Unit at a Small Refinery, JBFA-260-02-93, JBF Associates, Inc., Knoxville, TN, February 1994.

A Process Hazard Analysis of the Amine Plant and Sulfur Recovery Unit I at a Small Refinery, JBFA-260-01-93, JBF Associates, Inc., Knoxville, TN, February 1994.

Summary of Sprinkler Risk Assessment Study, JBFA-LR-251R-93, JBF Associates, Inc., Knoxville, TN, November 1993.

A Process Safety Management Implementation Plan for a Small Refinery, JBFA-239-93, JBF Associates, Inc., Knoxville, TN, November 1993.

Facility Risk Screening Study of a Tissue Mill, JBFA-112-93, JBF Associates, Inc., Knoxville, TN, May 1993.

Report on IAEA Mission to Rio de Janeiro, Brazil, BRA/9/041-04, International Atomic Energy Agency, Vienna, Austria, February 1993.

State of the Art of Level 1 PSA Methodology, NEA/CSNI/R(92)18 (Restricted), Nuclear Energy Agency, Issy-les-Moulineaux, France, January 1993.

A Process Safety Management Implementation Plan for a Paper Manufacturing Company, JBFA-266-92, JBF Associates, Inc., Knoxville, TN, January 1993.

BRAVO™2.0 Technical Reference, JBF Associates, Inc., Knoxville, TN, January 1993.

BRAVO™2.0 Reliability, Availability, and Maintainability (RAM) Analysis and Risk Assessment Software, JBFA-110-92, JBF Associates, Inc., Knoxville, TN, January 1993.

A Process Hazard Analysis of the High Activity Catalyst Project for a Polypropylene Plant, JBFA-130-92 (Vols. 1 and 2), JBF Associates, Inc., Knoxville, TN, November 1992.

A Process Hazard Analysis of a Three-Reactor Polypropylene Plant, JBFA-142-91, January 1992.

A Process Hazard Analysis of a Polyethylene/Polypropylene Developmental Plant, JBFA-131-91, September 1991.

Report on IAEA Mission to Krsko, Yugoslavia, YUG/9/025-19, International Atomic Energy Agency, Vienna, Austria, June 1991.

Fault Tree Analysis of a Scoop Drop System at a Manufacturing Plant, JBFA-105-91, JBF Associates, Inc., Knoxville, TN, March 1991.

A Failure Modes and Effects Analysis of a Proposed Electrical Load Center at a Refinery, JBFA-134-90, JBF Associates, Inc., Knoxville, TN, December 1990.

A Quantitative Risk Assessment of a Phenol Plant, JBFA-117-90, (Vols. 1 and 2), JBF Associates, Inc., Knoxville, TN, August 1990.

Reliability, Availability, and Maintainability Assessment of the PREPP Facility, JBFA-111-90, JBF Associates, Inc., Knoxville, TN, July 1990.

Reliability Analysis of Underground Fire Water Piping at the Paducah Gaseous Diffusion Plant, JBFA-101-89 (Vols. 1, 2, and 3), JBF Associates, Inc., Knoxville, TN, January 1990.

A Reliability Analysis of the Preliminary Design of the WEDGE-LOC® Lid Closure Mechanism for the NAC Combined Transport Cask, JBFA-LR-108-89, JBF Associates, Inc., Knoxville, TN, October 1989.

A Frequency Assessment of the Criticality Design Basis Accidents for PICS 10 MW High-Assay Freezer/Sublimers, JBFA-117-89, JBF Associates, Inc., Knoxville, TN, August 1989.

Hydrocarbon Flare System Challenges Caused by Failures in the 13.8 KV Electrical Distribution System, JBFA-114-89, JBF Associates, Inc., Knoxville, TN, July 1989.

Fault Tree Analysis of Fault-Tolerant Digital Control System Architectures, JBFA-LR-105-89, JBF Associates, Inc., Knoxville, TN, June 1989.

Facility Hazards Review of a Copper Mine and Associated Facilities, JBFA-109-89, JBF Associates, Inc., Knoxville, TN, April 1989.

Siting Risk Analysis for a Chemical Complex, JBFA-102-89, JBF Associates, Inc., Knoxville, TN, March 1989.

Facility Risk Review of the Mine, Extraction, Refining, and Utility Operations at a Large Industrial Facility, JBFA-122-88, JBF Associates, Inc., Knoxville, TN, October 1988.

Risk Management Program Plan for Mound, JBFA-120-88, JBF Associates, Inc., Knoxville, TN, September 1988.

Task 5 Draft Report: A Cause-Defense Methodology for Common Cause Failure Analysis, JBFA-116-88, JBF Associates, Inc., Knoxville, TN, August 1988.

Reliability, Availability, and Maintainability Application Study for a Proposed Waste Management System, JBFA-LR-104-88, JBF Associates, Inc., Knoxville, TN, July 1988.

Analysis of the Uncertainties in the Significance Factors Displayed in PRISIM, JBFA-101-88, JBF Associates, Inc., Knoxville, TN, February 1988.

Reducing the Costs of Producing and Updating PRISIM Computer Programs, JBFA-124-87, JBF Associates, Inc., Knoxville, TN, December 1987.

Scheduling PRA Updates: The ANO-1 Experience, JBFA-113-87, JBF Associates, Inc., Knoxville, TN, October 1987.

Dependent Failure Analysis Procedures Guide, JBFA-109-86, JBF Associates, Inc., Knoxville, TN, October 1986.

Risk Assessment Application to NRC Inspection — Interim Progress Report, JBFA-106-85, JBF Associates, Inc., Knoxville, TN, December 1985.

Relating PRA Information to Inspection Modules, JBFA-LR-112-85, JBF Associates, Inc., Knoxville, TN, September 1985.

Analysis of Dependent Failure Events and Failure Events Caused by Harsh Environmental Conditions, JBFA-LR-111-85, JBF Associates, Inc., Knoxville, TN, August 1985.

Demonstration Application for the Dependent Failure Analysis Procedures — Computer Applications, JBF Associates, Inc., Knoxville, TN, June 1985.

A Survey of β-Factor and C-Factor Applications, JBFA-LR-104-84, JBF Associates, Inc., Knoxville, TN, September 1984.

ROBERT W. STEGALL
Commanding Officer
United States Coast Guard Marine Safety Office
Port Arthur, Texas

EDUCATION

B.S. Marine Engineering, Massachusetts Maritime Academy, Buzzards Bay, Massachusetts, 1974.

SUMMARY OF EXPERIENCE

For the past 22 years, Mr. Stegall has served in the United States Coast Guard (Coast Guard), advancing through increasingly responsible engineering, inspection, technical, and supervisory roles. For the past 2½ years, he has served as Senior Engineering Inspector/Marine Inspector (rank of Chief Warrant Officer) for the Port Arthur (Texas) division of the Coast Guard. He has conducted detailed inspections of both U.S. and foreign vessels to ensure compliance with the U.S. Code of Federal Regulations and international treaties. He is also responsible for the inspection of 32 ships that are part of the U.S. Reserve Fleet. Due to his expertise, Mr. Stegall functions as the sole Steam Propulsion Inspector for the entire Gulf Coast region. In an administrative capacity as Command Duty Officer, he is second-in-command of the Port Arthur division, and ovesees port safety, security, and environmental protection. He handles and coordinates any problems or emergencies that the public or any ships, vessels, or offshore drilling rigs may encounter. Mr. Stegall's Coast Guard career highlights include the following:

- Developed and fine-tuned the vessel inspection program for Military Sealift Command Vessels by collaborating with vessel representatives to align maintenance goals with domestic and international requirements, resulting in decreased inspection time per vessel (from 40 to 16 hours)
- Served as Lead Marine Inspector on the conversion of a driving vessel, resulting in a landmark conversion under new Subchapter L regulations that set a precendent for similar conversions
- As Command Duty Officer, employed quick decision making and the ability to use all available resources to respond to an offshore well blowout and fire. Actions ensured the safe evacuation of 42 personnel. Coordinated response of the owner, seven Coast Guard air and water Search and Rescue units, two state agencies, and Minerals Management Service personnel. Located and secured the use of a diving support ship with high-capacity fire pumps, preventing total collapse of the rig and averting a potentially catastrophic oil spill. Scenario covered by all national news media
- Administered Auxiliary Engineering, Main Propulsion, and Damage Control divisions' Preventive Maintenance Schedule Programs aboard Coast Guard cutters *STORIS, SPENCER,* and *SENECA*, achieving a 100% rating on all ships over 7 years
- Designed, fabricated, and wrote operational procedures for new A/C and refrigeration systems that were replacing existing 50-year-old systems

- Served as Command Representative on *STORIS'* historic visit to Petropavlask, Russia (first U.S. war vessel to visit in 45 years). Event covered on National Russian Television
- Cited by the Commanding Officers of the last five commands for superior performance of duty while training unit personnel in preventative maintenance, engineering procedures, firefighting, and administration
- Cited by Headquarters for superior performance of duty in converting EPA's reportable quantities spill list from pounds to gallons so it could be understood by tankermen throughout the country. Report adopted by every Marine Safety Zone in the U.S. and incorporated into the Code of Federal Regulations. Still in use today
- During Haitian military coup d'etat, received Secretary of Transportation Gold Award for Superior Achievement (for the rescue of 590 Haitians) and two Humanitarian medals (for the rescue of 890 Haitians). Total of 3,840 Haitians interdicted in 3-month period. Also cited for maintaining all engineering equipment and maintenance during same period with no casualties
- Received the Coast Guard Achievement medal for superior performance of duty while serving as a recruiter. Awarded Recruiting Office of the Year (Norfolk, Virginia, office) 3 consecutive years and Recruiter of the Year 4 consecutive years

PROFESSIONAL TRAINING

Completed the following Coast Guard schools:

Machinery Technician	Inspection Department
Recruiter Training	Port Operations & Marine Environmental Safety
Chemical Ballistic Response	Damage Control Repair Party Leader
Marine Inspector Course	Caterpillar Diesel
Alco Diesel Engine	Waste Heat Boilers
Monitor Systems Maintenance	Oily Water Separators
Air Conditioning and Refrigeration	Dale Carnegie
National Tankerman Academy	

Multiple firefighting schools, including advanced aircraft firefighting

THOMAS F. ZANIN
Engineer VIII

EDUCATION

B.S.	Nuclear Engineering, Pennsylvania State University, 1984. Graduate courses toward an M.S. in Industrial Engineering, University of Tennessee (completion of degree in Summer 1998).

CERTIFICATION

Professional Engineer, the states of Tennessee and Ohio.

SUMMARY OF EXPERIENCE

Mr. Zanin, a project engineer for JBF Associates, Inc. and a registered professional engineer, has more than 14 years of experience in operations support, safety analysis, risk assessment, and reliability engineering. This includes 5 years as a nuclear-powered submarine officer. Currently, he is involved in assisting the U.S. Coast Guard (Coast Guard) in its Vessel Loss Exposure and Reliability Analysis Methodology (LERAM) program. In this program, Mr. Zanin participated in creating and testing a hazard and risk assessment methodology for application to Coast Guard vessels. In addition, he is working to integrate hazard and risk analysis results into Coast Guard loss prevention programs. In other areas, he has provided numerous risk assessment, reliability, and availability services for power plants and government agencies. Mr. Zanin is familiar with the reliability and loss prevention concepts in the OSHA process safety management (PSM) regulation (29 CFR 1910.119) and in the maritime International Safety Management (ISM) regulation. While with an electric power utility, Mr. Zanin assessed power plant operational risk and implemented the use of risk assessment methods in the management of change process. He is also trained in operations management, project management, and statistical process control.

1995 - Present	Engineer VIII, JBF Associates, Inc. Primary responsibilities include hazard and risk analysis and integrated loss prevention system development. Other responsibilities include (1) nuclear facility safety analysis and risk assessment, (2) process facility hazard analysis, (3) quantitative risk assessment, (4) reliability analysis, (5) fault tree and event tree analysis, and (6) proposal preparation.
1993 - 1994	Reliability and Performance Associates. Mr. Zanin provided a broad range of support in the areas of safety analysis, risk assessment, and reliability engineering, including the following specific projects: Martin Marietta Energy Systems, Inc./Advanced Neutron Source (ANS): Mr. Zanin was involved in developing system availability models and a reliability-centered maintenance program for ANS, particularly for the service water systems, chilled water systems, and control room ventilation systems. The system availability models employed a fault tree approach (IRRAS code). He was involved in ANS presentations made to a Department of Energy Reliability, Availability, and Maintainability (RAM) activities review team.

U.S. Army Chemical Weapons Demilitarization Program: As a risk assessment and hazard evaluation engineer, Mr. Zanin provided services to the U.S. Army by performing qualitative hazard assessments of Interim Holding Facilities (IHFs) once chemical weapons were excavated and placed into IHFs at different locations around the country pending shipment for disposal. Also as part of these efforts, Mr. Zanin ran the D2PC code (chemical agent dispersion code) to assess hazard distances for chemical agent releases.

Arkansas Nuclear One: Mr. Zanin was involved in the system reliability analysis for the Unit 1 systems (makeup and purification system and service water system) and the Unit 2 systems (feedwater control system and electrohydraulic control). The results of these studies were used in implementing a maintenance monitoring program. In addition, data from these studies were fed into the plant risk assessment model for core damage risk calculations.

1990 - 1993

American Electric Power (AEP). Mr. Zanin served as a risk assessment, safety review (10 CFR 50.59), and licensing engineer for AEP at the Columbus, Ohio, corporate office, where he supported the Donald C. Cook Nuclear Plant in Bridgman, Michigan. The following are examples of specific projects:

Individual Plant Examination (IPE)/External Events (IPEEE) Projects: Mr. Zanin was a probabilistic risk assessment (PRA) analyst for these risk assessment projects and developed more than 30 system fault trees and accident event trees. He conducted fault tree studies on electrical and mechanical systems (running and standby systems). He also assessed offsite release consequences using the MELCOR Accident Consequence Code System (MACCS). In addition, he was heavily involved in the seismic segment of the IPEEE project through information organization in support of the seismic plant walkdowns, walkdown participation, tracking development of the component fragilities, and finally in quantification of seismic accident event sequences.

Risk Assessment Applications: These applications included placing PRA evaluations in the management of change process, building a database of core damage frequency impacts based on various equipment failures, supporting waiver of compliance requests to the NRC using PRA arguments, and developing the PRA segment of the 10 CFR 50.65 Maintenance Rule for Cook Nuclear Plant. He also provided PRA assistance for motor operated valve (MOV) testing.

In addition, he evaluated a costly design change at a coal-fired generating station in the AEP system using PRA techniques (estimated $300,000 savings).

1989 - 1990

General Electric ASTRO Space. As a flight operations engineer for an earth observation satellite project, Mr. Zanin developed plans and procedures for spacecraft operations and worked with the ground station personnel at the Goddard Space Center near Washington, D.C. Integrated system knowledge was required.

1984 - 1989 U.S. Navy. Mr. Zanin was an officer onboard a nuclear-powered fast attack submarine. His involvement as a qualified watch officer in engineering plant operations and maintenance and oversight of industrial hazard safety, especially during a lengthy overhaul period, gave him an extensive background in light water reactor operations. He was heavily utilized as a watch officer for plant steam systems testing and for reactor testing. As the damage control officer, he oversaw reinstallation of the casualty response equipment onboard the ship during an overhaul period.

PROFESSIONAL TRAINING

Reliability in Maintenance, Process Safety Institute, Knoxville, TN, 1996.

Hazard Evaluation: Consequence Analysis Methods, Process Safety Institute, Knoxville, TN, 1995.

Hazard Evaluation: Qualitative Methods, Process Safety Institute, Knoxville, TN, 1995.

Process Hazard Analyses Leader Training Using the HAZOP and What-if/Checklist Techniques, Process Safety Institute, Knoxville, TN, 1995.

Human Reliability Analysis, Process Safety Institute, Knoxville, TN, 1994.

PUBLICATIONS AND REPORTS

An Assessment of WHEC-378 Vessel Crew Optimization Measures in Support of the Exemplar Project, U.S. Coast Guard Research and Development Center, JBF Associates, Inc., Knoxville, TN, February 1998.

Integrated Safety Assessment (ISA) Program — Coarse Hazard Analysis of the Integrated Support Center (ISC), Seattle, Washington, U.S. Coast Guard Research and Development Center, JBF Associates, Inc., Knoxville, TN, October 1997.

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APPENDIX L

June 16-17, 1997, Trip Report

JBF ASSOCIATES, INC.

1000 Technology Drive
Knoxville, Tennessee 37932-3353
(423) 966-5232 Fax (423) 966-5287

July 3, 1997

Mr. Richard L. Hansen
U.S. Coast Guard Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

TRIP REPORT: TRAVEL TO PORT ARTHUR, TEXAS, TO VISIT SHIPS HMP-119-97

Attached is the trip report for our visit to Port Arthur, Texas, which took place on June 16 and 17, 1997. As I told you on the telephone, personnel from the U.S. Coast Guard (USCG) Marine Safety Office, 2875 Jimmy Johnson Blvd., Port Arthur, TX 77640-2099, made excellent arrangements with the crews of four different ships, which helped ensure the success of our visit.

Specifically, marine inspector CWO Bob Stegall (1) established advanced contact with the crews, (2) discussed who we were and what our objectives were, and (3) arranged for a crew engineer to stay with us during each visit. CWO Stegall is also a very experienced inspector who provided us valuable insight and information pertinent to our project. We also appreciated the efforts of Lieutenant Gin Gonzales in rescheduling CWO Stegall's activities to accommodate our needs. We know that USCG inspectors have a busy schedule, and we certainly appreciate their efforts.

If you have any questions, please call me at (423) 671-5841.

Sincerely,

Henrique

Henrique Paula

HMP:adl

Attachment

c B. Burke (Contracting Officer)
W. H. Jones (RDC)

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Trip Report: Travel to Port Arthur, Texas, to Visit Ships
June 16 and 17, 1997
Port Arthur, Texas

Participants

The following people participated in our visits to ships in Port Arthur:

USCG Marine Safety Office:	CWO Bob Stegall
CG International (CGI):	George Cassa
JBF Associates, Inc. (JBFA):	Henrique Paula

Objectives

Our objectives for this visit were to familiarize ourselves with (1) the types of systems that contain pressurized flammable or combustible liquids, (2) the typical locations of these systems, including piping, and (3) the typical safeguards (administrative controls and engineered features) used to help prevent/mitigate accidental sprays of flammable or combustible liquids.

Activities and Results

We accomplished our objectives by visiting four vessels (see Table 1) and considering the following issues during each visit:

- Systems of interest (fuel oil, lubrication [lube] oil, hydraulic oil, etc.) and their location
- Potential causes of flammable/combustible material releases (e.g., hose failure)
- Potential ignition sources (e.g., hot exhaust piping from a diesel engine)
- Means of fire detection (e.g., smoke detectors, heat detectors)
- Means of release isolation (e.g., shutting off pump, closing isolation valve)
- Means of fire suppression (e.g., CO_2 system, dry chemical extinguisher)
- Potential for fire propagation to other vessel compartments
- Potential for disabling the propulsion system
- Potential for disabling the steering system
- Potential for human casualty

The following sections present a summary of the information collected during each visit.

OMS LIBERTY – The *OMS LIBERTY* is an offshore service vessel (OSV) owned and operated by Offshore Marine Services. This is a 255 gross tonnage, 173 net tonnage vessel. It is 155.7 feet long (breadth and depth are 38 feet and 12.6 feet, respectively) with a hull made of steel. This vessel has a crew of six.

The *bow thruster room* has a Detroit diesel engine located in a passageway leading to the engine room. This engine is used only for short periods of time during docking. Downstream of the engine's fuel oil pump, the fuel supply for the engine contains pressurized fuel oil, which could create an accidental spray of flammable/combustible liquids. One possible cause of a spray is hose failure (e.g., loosening due to vibration). The fuel supply hose is a wire-reinforced flexible hose, but there

Table 1 Trip Activities

Activity	Participants
Visit *OMS LIBERTY* *(June 16)*	Bob Stegall, George Cassa, and Henrique Paula
Visit *OMS SHELBY* *(June 16)*	Bob Stegall, George Cassa, and Henrique Paula
Visit *SS PETERSBURG* *(June 16)*	Bob Stegall, George Cassa, and Henrique Paula
Visit *CAPE VINCENT* *(June 17)*	Bob Stegall and Henrique Paula[a]

[a] George Cassa did not participate in the visit to the *CAPE VINCENT*. However, Mr. Cassa performed the pre-purchase reflagging survey on this vessel for the U.S. Maritime Administration (MARAD) and, therefore, is familiar with this vessel.

is no shield (double hoses[1] or equipment cover) that could help prevent the spray from reaching any of the equipment (engine parts and unrelated electrical equipment) in the bow thruster room. Other potential sources of releases are the fuel oil supply piping (upstream of the fuel oil pump), which comes from the engine room, and the lube oil system for the engine. The fuel oil supply piping has union connections that are not shielded, but the pressure is relatively low in this piping.

One source of release of pressurized liquids often mentioned in the literature is maintenance error while replacing/cleaning oil filters or strainers. In all diesel engines on this vessel, the filters cannot be replaced/cleaned during engine operation; the engine must be turned off for this maintenance activity. This is also the case for the diesel engines on the *OMS SHELBY*, discussed later in this trip report. Therefore, these OSVs appear to be less susceptible to this type of maintenance error. However, these OSVs are still susceptible to several other types of maintenance-related errors (e.g., incorrect installation of gaskets or flanges), which could lead to sprays when the engine is restarted.

One source of ignition in the bow thruster room is the engine exhaust piping, but this piping is insulated.[2] Other sources of ignition include electrical equipment (junction boxes, cables, etc.), which

[1] In a double hose (or pipe) arrangement, the high pressure fuel hose (pipe) is housed in an outer hose (pipe). Any fuel leakage is contained in the annular space between the hoses (pipes) and drained to a holding tank.

[2] The exhaust piping was identified as a potential source of ignition for all diesel engines in each of the four vessels we visited; in all cases, the piping had insulation, and the insulation was in place when the engine was running or in standby service. We did observe one exhaust piping without insulation for an engine that was undergoing maintenance. (Certain maintenance activities require removing the insulation.)

is encapsulated in metal conduits or metal cabinets.[3] There are no smoke or heat detectors in this room. A fire in this location would likely be detected by crew members making rounds in the bow thruster room or engine room, or by observation of smoke coming out of the exhaust air ducts for these locations.

Isolation of a spray of flammable/combustible liquids can be accomplished by shutting off the engine (stops the fuel oil pump and lube oil pump) and by closing one of several manual block valves in the fuel oil supply line. However, smoke and/or fire could make it difficult and dangerous to access the manual valves. Fire suppression can be accomplished by using portable fire extinguishers, fire hoses, or shutting off the ventilation system.

Obviously, a fire in the bow thruster room can disable the bow thruster system. Also, the bow thruster room is connected to the engine room by a passageway (no doors), and a fire in the bow thruster room is likely to allow smoke to enter the engine room. This could hinder crew activities in the engine room. In addition, the fire could propagate between these rooms if, for example, there were flammable or combustible materials (e.g., oil) in the bilge. This emphasizes the need for always cleaning spills of flammable or combustible materials. Other than fire propagation through the corridor, a fire in the bow thruster room is unlikely to affect the propulsion and main steering systems. For example, although there is electrical equipment in the bow thruster room, this equipment serves sewage and sanitary systems, not propulsion or steering systems.

The *engine room* has two main engines, two generator engines, and one engine for the compressed-air system. All five engines are Detroit diesel engines with similar characteristics regarding fire hazards, except for size and utilization (e.g., the compressed-air engine is smaller than the other engines, and it is rarely used). The engine room also houses (1) the hydraulic system, which contains high pressure hydraulic oil, (2) the transfer pump for the fuel oil system, which transfers oil from the storage tank to the day tanks, and (3) the fire water pump. The hydraulic oil system has several hoses and union connections that could fail and result in a spray of combustible liquids. A low pressure alarm in the hydraulic oil system should help alert the crew to such releases.

The causes of releases, ignition sources, means of detection, means of isolation, and means of suppression in the engine room are similar to the bow thruster room, and these discussions will not be repeated here. The fuel oil supply to each diesel engine can be isolated locally in the engine room using individual manual valves located underneath the removable sections of the floor plates. Another manual valve (outside the engine room) allows isolation of the fuel oil supply to all engines. Also, the wheelhouse has an indication/alarm panel for monitoring the status of all engines in the engine room, including a "common trouble alarm" for all engines except the bow thruster engine.

The only source of high pressure liquids in the *steering gear room* is the hydraulic oil system piping. However, except for electrical equipment, there are no sources of ignition in this location.

Fires in either the bow thruster room or the engine room can lead to human casualties. Discussions with the vessel crew indicated that the general approach for fighting fires in these rooms involves:

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[3] Electrical equipment was identified as a potential source of ignition for all releases involving sprays of flammable or combustible liquids; in all cases, electrical equipment was encapsulated in metal conduits or metal cabinets.

(1) assessing the location and magnitude of the fire, (2) attempting to extinguish the fire with portable extinguishers, (3) attempting to extinguish the fire by shutting off ventilation to these rooms, and, as a last resort, (4) attempting to extinguish the fire with firewater. (The same approach would be used by the crew of the *OMS SHELBY*, discussed later in this trip report.) Human casualties may occur when the crew tries to extinguish the fire locally with portable extinguishers (and maybe firewater); historical experience indicates that, because fire and smoke spread quickly, engine room fires typically lead to many casualties due to delayed evacuation from the room.[4]

OMS SHELBY – The *OMS SHELBY* is also an OSV owned and operated by Offshore Marine Services. This is a 92 gross tonnage, 68 net tonnage vessel. It is 91.3 feet long, and the hull is made of aluminum. This vessel has a crew of 4 and carries over 40 passengers.

This vessel has three Detroit diesel engines (engine room) for propulsion, two diesel engines (steering room) for the electrical generators, two diesel engines (engine room) for the air compressors, and a hydraulic system (engine room with piping to the steering system in the steering room). The causes of releases, ignition sources, means of detection, means of isolation, and means of suppression are similar to the diesel engines on the *OMS LIBERTY* (discussed earlier), and these discussions will not be repeated here.

One difference in the *OMS SHELBY* is that each of the three propulsion engines has a turbo charger, which contains high-pressure, high-temperature lube oil. Releases of lube oil in the turbo chargers are likely to result in a spray that can autoignite. Also, the surfaces of the turbo chargers are typically hotter than other parts of the engine, increasing the likelihood of ignition of any release of flammable or combustible materials in the engine room. Another difference between the *OMS SHELBY* and the *OMS LIBERTY* is that the fuel oil supply to each propulsion engine on the *OMS SHELBY* can be isolated individually from outside the engine room, while the fuel oil isolation valve outside the engine room on the *OMS LIBERTY* shuts off fuel oil to all diesel engines simultaneously.

SS PETERSBURG – The *SS PETERSBURG* is a tank ship owned and operated by MARAD. It was built in Sparrows Point, Maryland, in 1963, and was converted to an offshore petroleum discharge system (OPDS) configuration in 1995. This is a 27,469 gross tonnage, 18,685 net tonnage, 50,063 deadweight vessel. It is 708.30 feet long, and the hull is made of steel. This vessel has a crew of 31 and 22 additional personnel. Attachment A presents a copy of the Marine Inspection Certificate of Inspection for the *SS PETERSBURG*, which provides additional vessel details.

This vessel is propelled by a 15,000 HP, steam turbine. Two main steam-turbine electric generators and one standby auxiliary diesel (Caterpillar) generator are provided for the ship's service electrical power. In addition, an independent emergency diesel generator and switchboard are fitted outside of the engine room. (We did not visit the emergency diesel generator room.) Sources of potential sprays of flammable or combustible liquids are (1) the fuel oil system for the boiler, (2) the fuel oil and lube oil systems for the auxiliary diesel generator, (3) the lube oil system for the turbine and generator, and (4) the hydraulic oil in the steering room. For the propulsion and generator turbines, 600-psig superheated steam is generated by two boilers fired with heavy fuel oil. The boiler room is separated from the engine room by a water-tight, fire-tight steel bulkhead.

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[4] Masaru Iwamoto et al., *Engine Room Fire – Guidance to Fire Prevention*, Nippon Kaiji Kyokai (NK) (Japan's classification society), 1994.

The *fuel oil system* has flanged piping, suction strainers, heaters, and hoses at the furnace burners, all of which are pressurized. Flange failures and hose failures are certainly possible sources of sprays. However, the vessel crew indicated that these failures have not happened. These flanges are eight-bolt flanges, and the hose design pressure (1,200 psig) is significantly above the operating pressure. These design features may be responsible for the good operating history for the flanges and hoses. Nevertheless, vessel crew members suggested that the hoses, flanges, and gaskets should be checked/retightened as part of a periodic maintenance program.

There have been small releases of fuel oil in the burner area (mostly because of human error or because of failure of the excess flow check valve used at the burner). Also, vessel crew members indicated there are no bleeders for the suction strainers, which poses risks (opening equipment that is pressurized) to personnel during maintenance of the strainers. (The fuel oil is at about 200 °F and 350 psig.) This observation by crew members is significant because numerous human casualties have been reported to have occurred from failure to remove the pressure from fuel oil strainers and filters prior to maintenance.

Releases of fuel oil are likely to autoignite, and, although there are no smoke or heat detectors in the engine room, crew members are supposed to be in this location most of the time (detection by crew members should be quick). There are several ways to shut off the fuel oil pumps, including locally at the pump, from the board near the furnace, and from outside the engine room. Fire suppression can be accomplished using CO_2 and dry chemical extinguishers. There is no fixed fire protection system in this location.

The potential causes of releases and ignition sources for the *auxiliary diesel generator* are similar to the causes and ignition sources for the diesel engines on the OSVs discussed earlier in this trip report. However, this diesel generator has several additional safety features:

- It is located in the engine room within an acoustic enclosure with fire-rated walls
- The enclosure has a dedicated CO_2 system with two CO_2 bottles outside the enclosure
- The enclosure has a heat (thermal) detector that (1) shuts off the engine, (2) shuts off the fuel oil supply, (3) shuts off the air intake fan, (4) "seals" (closes all louvers) the enclosure, and (5) activates the CO_2 system

Sprays of pressurized oil could also occur from failures in the *turbine lube oil* system, but vessel crew members believe these are much less likely to occur than sprays from the fuel oil system. This location is also constantly occupied by crew members, and they expect these types of releases to be readily detected. Except for electrical equipment, which is encapsulated in metal cabinets or conduits, there are no other sources of ignition in this area. If a fire does occur, suppression can be accomplished using CO_2 and dry chemical extinguishers.

The only source of high pressure liquids in the *steering room* is the hydraulic oil system piping. However, except for some electrical equipment, there are no sources of ignition in this location.

CAPE VINCENT – The *CAPE VINCENT* is a freight roll on-roll off (ro-ro) ship owned and operated by MARAD. It was built in Italy. This is a 22,425 gross tonnage, 7,142 net tonnage vessel. It is 567.70 feet long, and the hull is made of steel. This vessel has a crew of 27 and 5 additional personnel. Attachment B presents a copy of the Marine Inspection Certificate of Inspection for the *CAPE VINCENT*, which provides additional vessel details.

This vessel is propelled by a 11,850 HP, diesel engine, and it has three smaller diesel generator engines. Sources of potential sprays of flammable or combustible liquids are:

- The fuel oil systems for the diesel engines, including booster pumps, fuel pumps, and several centrifuge purifiers (engine room)
- The lube oil systems for the diesel engines (engine room)
- The hydraulic oil systems in the engine room
- The fuel oil system for the auxiliary boiler (located in a dedicated room)
- The fuel oil and lube oil systems for the emergency diesel generator (dedicated room)
- The hydraulic oil system for the cargo doors (dedicated room)
- The hydraulic oil system in the steering room

The potential causes of releases and ignition sources for the diesel engines (fuel oil and lube oil) and hydraulic oil systems are similar to the causes and ignition sources for the diesel engines and hydraulic oil systems discussed earlier in this trip report, but all hydraulic oil systems in this vessel (as well as on the *SS PETERSBURG*) are segregated from sources of ignition (e.g., hot surfaces). Another difference from the other vessels visited is that all hoses from fuel pumps to engine injectors use the double hose arrangement. However, the vessel crew emphasized the need to properly install these safety devices (e.g., following maintenance). The vessel crew indicated that there have been few releases of pressurized liquids on this vessel. A rather unique spray did occur in the engine room when a large oil leak from one of the purifiers reached the bilge and drained under the flywheel, which sprayed oil through a large area in the room. The oil was cool, and this spray did not ignited.

There are several smoke detectors at different locations in the engine room, two smoke detectors in the auxiliary boiler room, one smoke detector in the steering room, but no smoke or heat detector in the hydraulic system room for the cargo doors.

This vessel has a central low-pressure (refrigerated) CO_2 system, which can discharge in any of six locations, and the CO_2 system can be activated simultaneously or individually for each location. In either case, the crew has to activate the system. The main engine room, the generator room, the purifier room, and the auxiliary boiler room constitute one of the six locations. That is, the CO_2 system discharges into all of these rooms simultaneously when activated for this location. Upon activation by a crew member, the system shuts off all pumps and purifiers, but the crew must activate the switches that close all louvers for the location. That is, the crew must activate both the CO_2 system and the switch(es) that close the louvers to ensure the most effective operation of the CO_2 system. All locations also have portable dry chemical fire extinguishers and firewater connections.

An interesting design feature of this vessel is that all air intakes for diesel engines take suction from the room where the engine is located. Thus, large fires will eventually lead to loss of all engines, resulting in loss of propulsion and the main electrical generators, particularly if the CO_2 system for this location is activated. Another observation is that, although the central CO_2 system provides a more automated and probably a more effective way of fighting large fires, it does create an asphyxiation hazard when it activates or leaks. In fact, there have been fatalities associated with similar CO_2 systems. Thus, adequate training regarding this hazard is crucial on this vessel and other vessels with CO_2 systems.

A feature that should be useful to help mitigate sprays of flammable or combustible liquids caused by severe failure of an oil pump discharge line is a low pressure switch that shuts off the pump upon low discharge pressure. The *CAPE VINCENT* has a low pressure switch, for example, on the discharge of the fuel oil pump for the auxiliary boiler.

Concluding Remarks

This trip provided us with a great deal of information about (1) the types of systems that contain pressurized flammable or combustible liquids, (2) the typical locations of the systems, and (3) the typical safeguards used to help prevent/mitigate accidental sprays of flammable or combustible liquids. This information has been very useful during our ongoing analysis of incident investigation reports.

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Attachment A

Marine Inspection Certificate of Inspection for the *SS PETERSBURG*

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ISSUED/ 10MAY97

EXPIRED/ 10MAY99

IMO NUM/ 6329044

VESSEL NAME:
PETERSBURG
HOME PORT:
NATL VESSEL DOC CTR
PLACE BUILT:
SPARROWS POINT, MARYLAND
OWNER:
U.S.DEPT. TRANSPORTATION (MARAD)
NASSIF BLDG, ROOM 2117
400 7TH STREET, S.W.
WASHINGTON, DC 20590

VIN:	CALL:	SERVICE:		
D291990	WJDC	TANK SHIP		
HULL MATL:	HP:	PROPULSION:		
STEEL	15000	STEAM TURBINE		
DATE:	GTON:	NTON:	DWT:	LENGTH:
15DEC63	27469	18685	50063	708.20

OPERATOR:
U.S.DEPT OF TRANSPORTATION(MARAD)
REG SHIP OPER. MRG-3700
365 CANAL ST, SUITE 2590
NEW ORLEANS, LA 70130-1137

LIFEBOATMEN/ 5 TANKERMEN/ 0

1 /MASTER	/1ST PILOT	6 /AB. SEAMEN	1 /CHIEF ENG'R	/FIREMEN
1 /CH. MATE	PIL.	3 /OR. SEAMEN	1 /1ST ENG'R	3 /OILERS
1 /2ND MATE	1 /RADIO OFF.	/DECKHANDS	1 /2ND ENG'R	
1 THIRD MATE	OPER		1 3RD AS ENG'R	

OTHER REQUIRED CREW/ DESCRIBE/
PASSENGERS/ 0 OTHER CREW/ 10 PERSONS IN ADDITION TO CREW/ 22
AND NO OTHERS TOTAL PERSONS/ 53

OCEANS

THIS TANK VESSEL IS EQUIPPED WITH DEDICATED CLEAN BALLAST TANKS AND COMPLIES WITH THE REQUIREMENTS OF 33 CFR PART 157 AND REGULATION 13B OF THE MARPOL PROTOCOL TO OPERATE AS A "PRODUCT CARRIER".

THIS TANK VESSEL IS EQUIPPED WITH AN INERT GAS SYSTEM AND COMPLIES WITH THE REQUIREMENTS OF 46 CFR 32.53 AND REGULATION 62 OF THE SOLAS PROTOCOL.

THE ELIMINATION OF FIREMEN/WATERTENDERS IS CONTINGENT UPON THE PROPER AUTOMATED OPERATION OF THE BOILER MANAGEMENT SYSTEM. ANY ALTERATIONS TO OR FAILURE OF THIS SYSTEM MUST BE REPORTED TO THE OFFICER IN CHARGE, MARINE INSPECTION, AT THE VESSEL'S FIRST U. S. PORT OF ARRIVAL.

JUNIOR ENGINEERS, DECK ENGINE MECHANICS, OR ENGINEMEN MAY BE SUBSTITUTED FOR ONE OR MORE OILERS.

*** SEE NEXT PAGE FOR ADDITIONAL CERTIFICATE INFORMATION ***

PETERSBURG (VESSEL NAME) — 2 (PAGE NUMBER) — CERTIFICATION DATE: 10MAY97

--- HULL EXAMS ---

-EXAM TYPE-	-NEXT EXAM-	-LAST EXAM-	-PRIOR EXAM-
DRYDOCK	20OCT98	20APR95	31DEC89
INTERNAL STRUCTURAL	10MAY00	10MAY97	31DEC94
CARGO TANK INTERNAL	10MAY00	10MAY97	20APR95

--- STABILITY ---

BOOK APPROVAL DATE/ 23JUL68 OFFICE/ BALMS

--- CARGO AUTHORITY ---

AUTHORIZATION/ GRADE "B" AND LOWER FLAMMABLE & COMBUSTIBLE LIQUIDS
46CFR SUBCHAPTER D AUTHORITY: HIGHEST GRADE/ B CAPACITY/ 387488 UNITS/ BBLS
46CFR SUBCHAPTER O AUTHORITY: PART 151/ NO PART 153/ NO PART 154/ NO

--- INSPECTION STATUS ---

BOILERS/STEAM PIPING

MAXIMUM STEAM PRESSURE ALLOWED/ 700 PSI

BOILER/PIPING ---IDENTIFICATION--	-----HYDRO----- LAST	NEXT	-----MOUNTS---- OPENED	REMOVED	---------VALVES--------- ---SAFETY-- SET	DATE	SUPERHEATER SET	DATE
STBD	20MAR96	20MAR01	28FEB96	28FEB96	Y	10MAY97	Y	10MAY97
PORT	20MAR96	20MAR01	28FEB96	28FEB96	Y	10MAY97	Y	10MAY97

PRESSURE VESSELS

TYPE	LOCATION	LAST	NEXT
AIR RECEIVER	BLR ROOM	28FEB96	28FEB99
AIR RECEIVER	BLR ROOM	28FEB96	28FEB99
DC HEATER	UPPER ENG. ROOM	28FEB96	28FEB99
STEAM GEN	BLR ROOM	28FEB96	28FEB99
AIR RECEIVER	AUX. DIESEL ENC	28FEB96	28FEB99
AIR RECEIVER	OPDS HOUSE	28FEB96	28FEB99
AIR RECEIVER	OPDS HOUSE	28FEB96	28FEB99

TAILSHAFT(S)

TAILSHAFT ID	DATE DRAWN	NEXT DUE DATE
MAIN (WATER)	20APR95	20OCT97
NDT	20APR95	

LIFESAVING

LIFEBOAT/RAFT IDENTIFICATION	SERVICED/ REFURBISHED	WEIGHT TEST	FALLS RENEWED	FALLS END/END
1 (STBD)	10MAY97	09MAY96	09MAY96	
2 (PORT)	10MAY97	09MAY96	09MAY96	
20DK/A030197	28APR97			
CJH/10/2105	28APR97			
20S/T0022/B0022	28APR97			
ER1693/US022	28APR97			

PETERSBURG (VESSEL NAME) | 3 (PAGE NUMBER) | CERTIFICATION DATE: 10MAY97

--- LIFESAVING EQUIPMENT ---

	NUMBER	PERSONS		REQUIRED
TOTAL EQUIPMENT FOR		53	LIFE PRESERVERS(ADULT)...	64
LIFEBOATS(TOTAL).......			LIFE PRESERVERS(CHILD)...	
LIFEBOATS(PORT)*.....	1	53	RING BUOYS(TOTAL)........	24
LIFEBOATS(STARBD)*...	1	53	WITH LIGHTS*...........	12
MOTOR LIFEBOATS*.....	2	106	WITH LINE ATTACHED*....	2
LIFEBOATS W/RADIO*...	2		OTHER*.................	10
RESCUE BOATS/PLATFORMS.			IMMERSION SUITS..........	64
INFLATABLE RAFTS.......	6	110	PORTABLE LIFEBOAT RADIOS.	2
LIFE FLOATS/BUOYANT APP			EQUIPPED WITH EPIRB?.....	YES
WORKBOATS (NOT REQUIRED)			(* INCLUDED IN TOTALS)	

--- FIRE FIGHTING EQUIPMENT ---

TOTAL HOSE LENGTH/ 3750 NUMBER OF FIRE AXES/ 7 NUMBER OF FIRE PUMPS/ 3

FIXED EXTINGUISHING SYSTEMS

SPACE PROTECTED	AGENT	CAPACITY
PAINT LOCKER	CO2	150
PAINT LOCKER	CO2	100
ENGINE ROOM/CARGO DECK/PUMP RM	FOAM	660
PUMP ROOM	NOT CLASSED	
AUXILARY DIESEL ENCLOSURE	CO2	200
OPDS HOUSE	CO2	700

FIRE EXTINGUISHERS - HAND PORTABLE AND SEMI-PORTABLE

A-II	B-I	26 B-II	12 B-III
B-IV	1 B-V	C-I	C-II

*** END ***

[Blank]

Attachment B

Marine Inspection Certificate of Inspection for the *CAPE VINCENT*

[Blank]

ISSUED/ 27JUN96

EXPIRED/ 27JUN98

IMO NUM/ 8211291

VESSEL NAME:
CAPE VINCENT
HOME PORT:
NATL VESSEL DOC CTR
PLACE BUILT:
ITALY
OWNER:
U.S.DEPT OF TRANSPORTATION(MARAD)
NASSIF BUILDING, RM 2123
400 7TH ST SW
WASHINGTON, DC 20590

VIN:	CALL:	SERVICE:		
D993579		FREIGHT SHIP		
HULL MATL:	HP:	PROPULSION:		
STEEL	11850	DIESEL REDUCTION		
DATE:	GTON:	NTON:	DWT:	LENGTH:
	22425	7142		567.70

OPERATOR:
U.S.DEPT OF TRANSPORTATION(MARAD)
REG SHIP OPER. MRG-3700
365 CANAL ST, SUITE 2590
NEW ORLEANS, LA 70130-1137

LIFEBOATMEN/ 6 TANKERMEN/ 0

1 /MASTER	/1ST PILOT	6 /AB. SEAMEN	1 /CHIEF ENG'R	/FIREMEN
1 /CH. MATE	PIL.	/OR. SEAMEN	1 /1ST ENG'R	3 /OILERS
1 /2ND MATE	1 /RADIO OFF.	/DECKHANDS	1 /2ND ENG'R	
1 THIRD MATE	OPER		1 THIRD ENG'R	

OTHER REQUIRED CREW/ DESCRIBE/
PASSENGERS/ 0 OTHER CREW/ 9 PERSONS IN ADDITION TO CREW/ 5
TOTAL PERSONS/ 32

*****OCEANS*****

THIS VESSEL HAS BEEN GRANTED MODIFIED INSPECTION INTERVALS IN ACCORDANCE WITH ANNEX I TO MARAD/CG MOU ON RRF VESSELS. FIVE YEAR DRYDOCK INTERVALS ARE PERMITTED, PROVIDED ACTIVATION TIME DOES NOT EXCEED THREE YEARS BETWEEN HAULOUTS.

JUNIOR ENGINEERS, DECK ENGINE MECHANICS OR ENGINEMEN MAY BE SUBSTITUTED FOR ONE OR MORE OILERS.

THE RADIO OFFICER IS NECESSARY ONLY IF REQUIRED BY THE FEDERAL COMMUNICATIONS COMMISION.

IMMERSION SUITS ARE NOT REQUIRED WHEN THE VESSEL IS OPERATING IN THE ATLANTIC OCEAN BETWEEN 32 DEGREES NORTH LATITUDE AND 32 DEGREES SOUTH LATITUDE OR IN ANY OTHER WATERS BETWEEN 35 DEGREES NORTH LATITUDE AND 35 DEGREES SOUTH LATITUDE.

*** SEE NEXT PAGE FOR ADDITIONAL CERTIFICATE INFORMATION ***

CAPE VINCENT (VESSEL NAME) — 2 (PAGE NUMBER) — CERTIFICATION DATE: 27JUN96

--- ITC TONNAGES ---

GROSS/ 22425 NET/ 7142

--- HULL EXAMS ---

-EXAM TYPE-	-NEXT EXAM-	-LAST EXAM-	-PRIOR EXAM-
DRYDOCK	31JUL99	01JUL94	
INTERNAL STRUCTURAL	31JUL97	01JUL94	

--- STABILITY ---

LETTER BOOK APPROVAL DATE/ 27OCT94 OFFICE/ GMSC

--- INSPECTION STATUS ---

PRESSURE VESSELS

TYPE	LOCATION		LAST	NEXT
AIR RECEIVER	ENG RM	01JUL94	27JUL96	31JUL99
AIR RECEIVER	ENG RM	01JUL94	27JUL96	31JUL99
AIR RECEIVER	ENG RM	01JUL94	27JUL96	31JUL99
AIR RECEIVER	ENG RM	01JUL94	27JUL96	31JUL99
AIR RECEIVER	FOCS'L	01JUL94	27JUL96	31JUL99
OTHER	CO2 RM		01JUL94	31JUL02
AIR RECEIVER	ENG RM	01JUL94	27JUL96	31JUL99

LIFESAVING

LIFEBOAT/RAFT IDENTIFICATION	SERVICED/ REFURBISHED	WEIGHT TEST	FALLS RENEWED	FALLS END/END
STBD	12JUL96	12JUL96	06JUL94	12JUL96
PORT	07JUN96	07JUN96	11JUL94	28FEB95
20DKY030993	29MAY96			
20DKE031093	29MAY96			
20DKV050993	29MAY96			

--- LIFESAVING EQUIPMENT ---

	NUMBER	PERSONS		REQUIRED
TOTAL EQUIPMENT FOR		32	LIFE PRESERVERS(ADULT)...	39
LIFEBOATS(TOTAL)........	2	64	LIFE PRESERVERS(CHILD)...	5
LIFEBOATS(PORT)*......	1	32	RING BUOYS(TOTAL)........	18
LIFEBOATS(STARBD)*...	1	32	WITH LIGHTS*...........	9
MOTOR LIFEBOATS*.....	2	64	WITH LINE ATTACHED*....	2
LIFEBOATS W/RADIO*...			OTHER*.................	9
RESCUE BOATS/PLATFORMS.			IMMERSION SUITS..........	39
INFLATABLE RAFTS.......	5	100	PORTABLE LIFEBOAT RADIOS.	
LIFE FLOATS/BUOYANT APP			EQUIPPED WITH EPIRB?.....	YES
WORKBOATS (NOT REQUIRED)			(* INCLUDED IN TOTALS)	

--- FIRE FIGHTING EQUIPMENT ---

TOTAL HOSE LENGTH/ 3700 NUMBER OF FIRE AXES/ 8 NUMBER OF FIRE PUMPS/

*** SEE NEXT PAGE PLEASE ***

CAPE VINCENT (VESSEL NAME) | 3 (PAGE NUMBER) | CERTIFICATION DATE: 27JUN96

FIXED EXTINGUISHING SYSTEMS

SPACE PROTECTED	AGENT	CAPACITY
ENGINE ROOM	CO2	8490
RO/RO EMBARKATION DECK	CO2	55450
RO/RO CARGO HOLD	CO2	35332
INCINERATOR ROOM	CO2	78
EMERGENCY GENERATOR ROOM	CO2	212

FIRE EXTINGUISHERS - HAND PORTABLE AND SEMI-PORTABLE

11 A-II	B-I	9 B-II	B-III
B-IV	1 B-V	C-I	6 C-II

--- CERTIFICATE AMENDMENTS ---

1. PORT AMENDING/ PATMS DATE AMENDED/ 17DEC96

-AMENDMENT-

ADDRESS CHANGED THIS DATE AS PER MARAD LETTER TO REFLECT NEW OPERATOR.

*** END ***

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